

The
SURGICAL CLINICS
of
NORTH AMERICA

NATIONWIDE NUMBER

PHILADELPHIA AND LONDON
W. B. SAUNDERS COMPANY

1919

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SYMPOSIUM ON ORTHOPEDIC SURGERY

EDWARD L. COMPTON, M.D., *Consulting Editor*

COMMUNUTED AND SEGMENTAL FRACTURES OF THE LEG

KELLOGG SPEED, M.D., F.A.C.S.*

THE severe blows of automobile, industrial and sports accidents lead frequently to comminuted and multiple fragmented or segmental types of fractures of the legs which are difficult to treat in a uniform manner. The outcome in many instances leaves much to be desired from a cosmetic, anatomical and functional standpoint and no one line of treatment can be advanced as satisfying the demands of ideal care and perfect results.

PATHOGENESIS

The causes of such fractures may be either direct violence on the leg as in injury received from the hub, fender or wheel of a moving automobile or machinery, or indirect violence from torsion of the leg as received in falls from low heights, the accidents of sports as in golf, track, running, hurdling, pole vaulting or base sliding in our national game. Direct violence leads to the transverse and oblique type of fractures and may cause comminution of the tibia and/or fibula of the most severe grade. There are concomitant injuries of the soft parts from pressure and abrasion but not necessarily open wounds. This presentation does not aim to cover open fracture of the leg. In some instances of closed fracture; secondary infection and necrosis of tissue covering the bones of the leg may ultimately put the injury into the class of open fracture.

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Twisting or torsional violence received by the leg, as in falls into holes or off small elevations as well as those sustained in sports mentioned, causes spiral fractures of the leg bones with the tibia suffering most of the damage. These fractures are not always pure spirals but may be complicated while the fracture is in progress by sudden stoppage of the moving limb by obstacles such as the ground or curb, permitting some direct violence force to be displayed against the spiral separation of the bone or bones and leading to additional fragmentation as in transverse or oblique fractures and consequently to comminution. Likewise this secondary part of the violence may damage soft tissue coverings of the leg in addition to any injury resulting from the spiral fracture which itself may have led to puncture of the leg coverings and projection out into the air of the sharp bony points always present in spiral fractures. Late necrosis from pressure damage and interfered-with blood supply of soft tissues and integument may, as in the first class of direct violence fractures, end up as an open wound with local ulcer leading to the planes of bone separation. These fractures also, because of the considerable amount of bloody extravasation about the injured area coming from the bone or periosteum alone, may lead to the development of massive bullae loaded with bloody serum, which raise the epidermis and are easily ruptured and subsequently infected, if not prepared for in the very first acts of treatment.

It is seen consequently that leg fractures, in the tightly packed limb encased in a fascial envelope, may lead to secondary disaster on account of the changes in the tissues about the fracture incidental to the pressure exerted by the cause or the displacement of the fragments or the hemorrhage and edema developing in the limb. Blood vessels and nerves in the limb may suffer primary injury but these are relatively uncommon except for rupture of thin-walled veins. All ages and classes of individuals from the young infant through the rough playing adolescent into adult life including the housewife with her domestic accidents of stair and ladder climbing, the artisan in the factory, the adult athlete and the middle and older aged with already developed poor circulation, varicose veins and edema in the legs or overweight body, suffer these fractures.

PURPOSES OF TREATMENT

All classes and types of leg fractures require certain elementary rules of treatment, because the leg must sustain the whole body weight without pain or shirking in order that the individual may get about and work. The essential purposes of treatment may be listed as:

1. Relief of agony.

2. Restoration to normal of any axial deviations leading to angling or rotation to avoid unhappy positions of the foot or changes in the axis of the knee joint which might interfere with the weight-bearing line of the leg and thus cause disability.

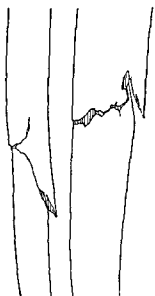
3. Prime consideration for the integrity of the soft parts covering the leg and bones. This means care in handling the injured limb to avoid additional or secondary damage to soft parts such as might accrue from skin puncture by bony points, vessel or nerve damage against rough or sharp bone surfaces and avoidance of pain and additional local bloody extravasation from unwise or rough manipulation.

4. Maintenance of the position of bone reduction obtained by treatment until the callus or bone scar can hold without external assistance during acts of weight bearing.

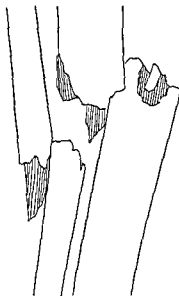
IMMEDIATE AND EARLY TREATMENT AND ASSESSMENT OF THE INJURY

What are the practical points in treatment on this basis? First comes the handling of the broken leg at the site of injury to avoid some of the secondary damages briefly mentioned in my first remarks. The angled, distorted and maybe greatly soiled leg may be gently straightened and held in alignment before any attempt is made to move the injured person. He must not be encouraged to stand up, roll over or move at all in an attempt to see if he can do such things. Where there is the slightest suspicion of a broken bone, *treat the injury from the earliest possible moment as a fracture*. A very easy and practical method is to place the leg gently, straightened out, in a soft pillow or thick blanket which may be pinned around the leg or bound on with bandage or handkerchief to permit transportation to a place for final care. Boards padded with coats, shirts or sweaters, and Thomas leg splints have been used but the most valuable factor in preparation for transportation is "gentleness." It is not necessary to strip off clothing at this stage. If a medical man sees him this early he may quickly, without disturbance of the injured, assure himself about the arterial beat in the dorsalis pedis artery or observe power to move toes and foot muscles to assay nerve damage.

When the patient has arrived at a place for proper permanent care, clothing which impedes treatment is gently removed without disturbing the position of the leg. If feasible and the place of treatment is a hospital, a roentgenogram in two axes, anteroposterior and lateral, of the leg may then follow without additional disturbance and properly in the sequence of treatment. An assistant must hold the foot and the patient is placed on a fracture table when one is available. The leg and foot may then be washed with soap and warm water, covering with sterile sponges any areas of threatened puncture or even a tiny opening in the skin, which is later cleansed and given particular attention, after the gross dirt on the leg has been removed. In some instances the hair on the leg must be shaved. The skin of leg and foot must be thoroughly cleansed and then washed with 70 per cent alcohol, or one of the dye anti-septics may be applied if the surgeon has confidence in them. During this interval the roentgenograms may have been developed and the extent of the fracture, meaning its character whether transverse or oblique as the result of direct violence or spiral as following torsional violence, along with the amount



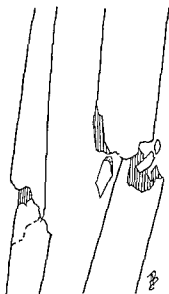
A



B



C



D

Fig 1 (Case of R. W.)—Drawings from x-ray films Baseball and football player injured sliding to base A, 7/2/47 Anteroposterior view twenty-four hours

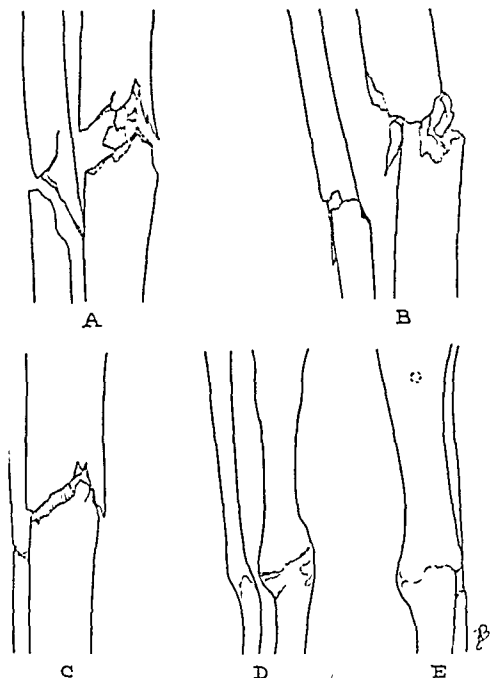


Fig 2 (Case of R. W., *continued*).—A, B, 7/26/47: Anteroposterior film taken on fracture table shows good reduction with some overpull and lateral view (B) shows obdurate impalement of fragments in spite of overpull. Patient transferred this date to plaster of Paris after attempt at local manipulation using pin in upper end of tibia and one through heel, as it was not expected that any better reduction could be had. C, 8/30/47: In lateral plane reduction—good callus forming—in cast. D, E, 5/8/48: End result. Firm bony callus slightly palpable under skin, axial alignment in both planes good, no shortening, strength returned in leg, patient playing ball again. Note slight amount of bone formed around Steinmann pin hole at proximal end of tibia from tearing of periosteum and some hemorrhage at time of insertion. This might be lessened by a smaller pin or a Kirschner wire—but the latter is not strong enough to stand the pull exerted by the patient. Tibia is now slightly exuberant but

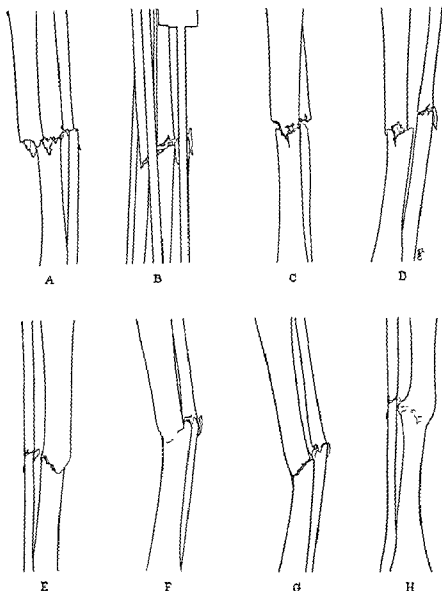


Fig. 3 (Case of A. Z.) —Drawings from x-ray films. The patient, a very tall boy was injured while working on delivery truck. After the fracture bullae rapidly developed on leg, forbidding open operation. A, B, 10/30/16. After a day's skeletal traction in heel. The extremely jagged surfaces of tibia and an intermediate fragment made it look as if no reduction could ever be obtained or certainly only by dangerous overpull which seems already started in anteroposterior view (A). Local manipulation to aid the reduction was attempted with the patient lying in traction. C, D, 12/3/46. Reduction is now accomplished and a fair apposition has been obtained. Amount of weight pull could now be diminished, guarding against occurrence of buckling or angling at fracture site. The limb was put in plaster in this position, leaving skeletal traction by means of Steinmann pin in heel, reinforced in plaster from base of toes to midthigh. E, F, 3/22/47: After five months union started with slight posterior dishing of leg bones. The patient was in walking plaster at this time. G, H, 6/24/47. Firm union with slight posterior dishing, no pain, no shortening, back at work.

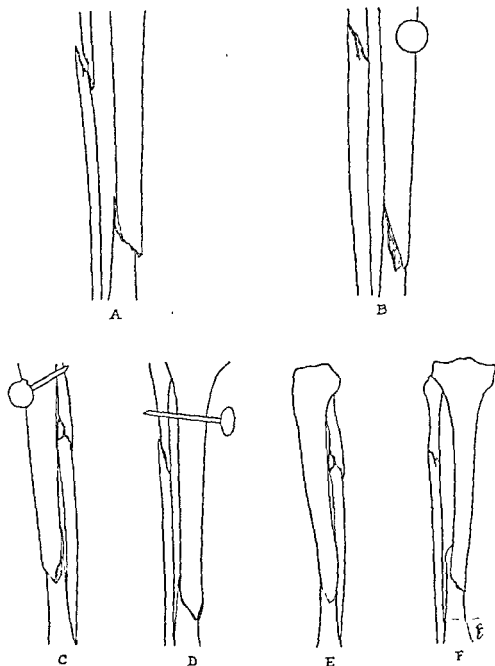


Fig. 4 (Case of Mrs. J.).—Drawings from x-ray films. A, 10/11/47: Spiral frac-

slip and slide past each other from muscle spasm or lack of support is manifest. B, 10/11/47: Position obtained in six hours after skeletal traction through heel

in copying the roentgenogram is simply the shadow of the round pulley attached to the pin over which wire attachments are run. E, F, 4/3/48: Result after bony union. No shortening, no local pain or swelling. Some new bone formation at inner margin of tibia from nail puncture. The slight angulation at fracture site of tibia will slowly disappear.

of comminution and fragmentation can be read in the film taken in two axes. The mistake must not be made of exposing too small an area of the leg to the x-ray film *The whole length of the leg from ankle joint to knee joint should be seen in the roentgenogram.* It often happens that both bones are broken, and the fibula, especially in spiral fractures, may be broken at considerable distance from the fracture of the tibia and overlooked if the film fails to display the shadows of the full length of the leg bones.

Reading the films will disclose the main points of the bony displacements—whether the principal fracture is spiral with sharp terminating

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siderable size involving complete isolation of a shaft fragment, three or more inches in length, not always seriously out of alignment but certainly cut off from the main blood supply of the shaft as a whole when the nutrient artery and its medullary branches are considered. Such a fragment may be angled, rotated, comminuted within itself, split and deformed, but it may retain a considerable portion of its own local periosteal blood supply which may finally save it from complete aseptic necrosis. Having been heavily traumatized and thus lost considerable blood supply, such fragments may undergo a rather slow necrosis. Then their roentgenologic shadow becomes denser, they fail at their margins to enter into a normal rate of bony union and thus complicate and prolong the process of healing. Final full restoration of bone continuity would then depend on a slow creeping substitution of this bone by new bone built up laboriously by slowly ingrowing new blood supply. Here is where any retained periosteal blood supply, escaping the violence of the original trauma, may be of great assistance. Failure to recognize this pathological situation in complicated comminuted leg fractures may lead to unwise surgery on bone fragments struggling for life and barely able to hold their own.

It must be definitely settled that the fracture involves only one or both bones. Bearing this in mind—if only one bone is broken the surgeon may hopefully expect the remaining intact bone, usually fibula, to be of considerable assistance to him in maintaining length and some splint support of the leg. On the other hand, the unbroken bone may become an obstacle in achieving by any means quite perfect kissing adaptation of the fracture surfaces in the broken bone.

Many hospitals and certainly many men handling these fractures are not prepared in equipment and training to perform open operations on the bones of the leg, although practically no one would deny that an operation to apply a metal plate or transverse screws may result in hair-line reductions and a fulfilling of some of the ideal requirements of treatment. That type of surgery requires long and well controlled training and should not be entered upon casually by a man not qualified. Most of the laity realize this and often permission to operate cannot be obtained.

The surgeon then may have to adopt less danger-enticing measures which hopefully will fill the demands of treatment and produce a satisfactory result. These may involve the use of skeletal traction and counter-traction with the additional help of external splinting.

REDUCTION BY FIXED TRACTION FOLLOWED BY SPLINTING

If there is a little displacement of the major fragments of the leg bones, which may be broken at nearly the same level, especially in the case of a young child, it may be possible, by applying skin traction with adhesive tape over well padded malleoli, to pull the fragments into full length and complete axial replacement checked in both planes by x-ray films and held sustained by padding under the thigh. The leg is properly fixed to an overhead supporting bar such as is found on the fracture table. If this can be done with the leg under tension on the fracture table, with the weight-bearing line of the leg restored from the anterior-superior spine of the ilium through the patella, through the middle of the ankle mortise and on out through the second toe, a rather snug-fitting plaster-of-paris encasement may be applied from high thigh to base of toes or even beyond the end of the toes on the sole of the foot, with foot held at right angles to the leg. If rapid swelling or edema is feared this plaster may be split through most but not all of its layers ready for quick cutting if pain or edema and numbness in the foot follows. The leg should be elevated on pillows.

Even with the most carefully applied plaster, after what appears to be perfect reduction as demonstrated by the roentgenogram, this treatment may lead to difficulty from development of blebs on the leg, edema and pressure within the splint and circulation interference. Also as the days go on the spasm of muscles in the leg or their swelling and shortening may so affect the fragments that secondary shortening and angulation may appear in the leg which has been lying quietly, well encased in plaster. Later, after removal of the splint, measurement and x-ray examination will prove these deficiencies and a hoped-for ideal result will be lost, the result being slight shortening and possible axis deviation which may lead to limp, poor posture of the foot for weight bearing, and a certain small percentage of permanent disability. However, this may not be so great as to be unbearable nor run the risk entailed by open operation under unfavorable circumstances.

REDUCTION BY CONTINUOUS TRACTION—SKELETAL PULL— SUSPENSION

If the treatment just described is not practical and promises to lead to a certain unhappy result, continuous traction on the leg may be advisable. On account of the short segment of leg, ankle and foot found in many of these injuries, skin traction with adhesive is not trustworthy for long-continued traction even when the patient is lying in bed and the supporting splint permits flexion at the knee to relax leg and thigh

muscles. Consequently some form of skeletal traction is often required. *usually, preferably, a properly sized Steinmann pin inserted through the middle of the calcaneus under strict aseptic precautions, or a Kirschner wire clamped into the metal horseshoe for steady traction as the leg lies in a Thomas splint.* The pull of the wire may cut through the calcaneus. This traction must pull the leg out to full length and correct the displaced axis, if any. It must not be overweighted, it should be in balanced suspension and should not overpull the fragments to cause distraction between their surfaces. When first applied it should have plenty of power. I often use 20 pounds or even more weight on a leg and observe by portable film within twenty-four hours any tendency to overpull.

This method holds the foot at right angles in a Thomas splint, and it permits immediate inspection of the skin and soft tissues of the leg. It also allows an application of local pressure or manipulation in case there are intermediate fragments of bone which are difficult to draw into alignment. Light blows on such malaligned fragments against the padded skin may, early in the forceful traction, jar them happily into line as the leg lies in traction in the splint. The lateral x-ray film must assure the surgeon that there is no sagging of any fragment of the broken leg bones which will lead to posterior "dishing" or backbending of the shafts of the bones. Every precaution must be taken against overpulling of fragments for any length of time because removal of some of the weight used for traction will not insure a return to proper apposition of fractured surfaces might lead to sagging angulation and delayed or nonunion in nature's inability to close up the hiatus existing between fracture surfaces.

These patients require intelligent, interested observation by their surgeon at least twice a day along with gentle, noninterfering nursing care. This line of treatment confines the patient to his bed—it interferes with customary exercise and activity and slows down his metabolism which may lead to lessened spontaneous bone-healing effort. Any large

displaced roentgenograms for loss of vitality, aseptic necrosis and disintegration of the bone. No premature movement, weight bearing or in instances of subsequent nonunion studies such a series of films to assure suspected is alive and could withstand being away. application of bone vitality struggling to regain. the best at this stage in

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injury. But it must conform to the demands mentioned at the beginning of this presentation. Consequently accurately controlled and relatively fool-proof methods must be practiced by and large over the country. The use of inserted metal pins which permit manipulative correction of bony displacements by partial penetration into the shafts of the tibia affixed by external clamped-on bars has not yet become an orthodox means of fracture treatment. There is no doubt that excellent results have been obtained by these means but there are too many pitfalls and chances for error and infection and perhaps too little regard for the fact that it is the bone healing itself which must bear the final burden of use along with an unwise practice of permitting immediate ambulation and weight bearing during the early stages of bony healing, thus militating against a natural firm bony union. The use of intramedullary metal pins in leg bones is likewise far from accepted as a means of permanent fixation and treatment. Both of these methods require high class surgical application and an armamentarium of expensive materials of multiple sizes. In the history of fracture treatment both methods have been tried and abandoned.

FIXED SKELETAL TRACTION FOLLOWED BY SPLINTING AND DELAYED AMBULATION

Skeletal traction and support, permitting reasonably safe ambulation and activity when supported by encasing plaster, has been used for years. It likewise falls short in some instances of giving an ideal result.

Metal pin or wire traction, preferably Steinmann pin, can be used to correct support and furnish the background for enduring and sustaining external splintage which permits the patient to become ambulatory and thus be restored to metabolic balance.

A suitable sized Steinmann pin is inserted through the calcaneus under aseptic conditions and the patient is put on a fracture bed or table where mechanical traction may be applied to the leg via the pin. The length of leg is pulled out to normal, displaced intermediate fragments are manipulated into position by local pressure or padded pounding and the lateral views of the leg bones shown in the roentgenogram are checked. To ensure the holding of leg length and the maintenance of axial correction, thus avoiding sagging or slipping off of spiral or other types of displacement of the fragments, a second metal pin is then inserted transversely through the upper end of the tibia just about at the level of the tubercle. It must go clear across the leg through good holding bone and must not split the tibia, must not enter into the hematoma about the fracture if possible, nor add to the pathologic involvement present. This pin, fitted with suitable pulley riders, permits the surgeon to manipulate the proximal part of the leg bones and then to hold them in the position of maximal reduction by wire supports running to an overhead bar. After dressing coverage of nail holes in a manner that will prevent seepage of water from

unsterile plaster bandages, the leg from upper thigh to base of toes is encased in plaster-of-paris and rechecked by x-ray for position, to avoid overpull.

After the plaster hardens sufficiently, the leg is removed from its fixed traction in the table. Ambulation may follow within a few days depending on the patient's ability to handle crutches, but no weight bearing may be permitted on this reduced leg fracture. An extra heel and sole of $\frac{3}{4}$ inch may be applied *under the shoe of the well foot* in an effort to avoid the temptation of resting the injured foot on the floor. Corks are taped on the pointed projecting ends of the Steinmann pins. The patient is encouraged in activity on crutches. In four weeks a checking roentgenogram is made, mainly for position, but it may happily show callus formation. The plaster is kept on the leg for eight to twelve weeks depending on the comminution and severity of the fracture. After that time the plaster is cut away circularly around the pointed ends of the pins, the skin surface exposed by picking away the dressings, the pointed ends of the Steinmann pins are sterilized by hydrogen peroxide followed by three coats of tincture of iodine, and the pins are withdrawn. A light gas anesthesia may be required. Wounds of pin perforations are covered with sterile dressing, the enveloping plaster cast on the leg is split and removed with great care.

The limb, placed on a soft pillow, is now x-rayed to determine position and amount of bone healing of fragments. If healing is suitably advanced, the leg is covered by a sterile stocking which covers the dressings over the pin holes, and over light padding with sheet wadding and small pieces of felt a circular plaster-of-paris encasement is put on the leg with reasonable snugness, extending to just below the knee and enveloping the foot, permitting leg flexion. This cast may include a walking iron stirrup—but weight bearing on the broken leg even with this device is *not* permitted until the callus shows extensive formation and maturity with ability to maintain the position of bone fragments by itself.

WALKING IRON STIRRUPS

I believe the walking iron stirrup support, which is often put on at the time of the first plaster application, following attempted reduction of leg fracture, *is not* a good thing and freedom with permission ens, there is risk of improper transmission of body weight away from and by-passing the fracture site to the broad tuberosity portion of the tibia because if any padding is used or the edema and swelling in the leg subside or atrophy develops in the volume of leg muscles as it is bound to do, looseness follows and the patient is bearing direct full weight on the still unhealed fracture. This may not be so serious in a perfectly transverse fracture which is reduced end-to-end and *cannot angulate much out of axis inside the splint*, but it usually leads to shortening, overriding and some angulation with interference with the normal rate of bone healing in oblique

and spiral fractures. If perchance there has been a little overlap and separation of fragments this walking on the inserted iron may act favorably to promote bony healing. Most walking irons, applied as a rule, are improperly applied. Not enough attention is given to the detail of making fitting the underlying portion of the plaster surface onto which the iron is applied in the proper axial direction, well toward the anterior side where the shoe heel might lie, and held by plenty of sustaining wraps and wrappings of additional plaster. Many irons are likewise too short and the pressure of the patient's weight bearing falls completely to one side of the fracture site.

The function of the walking iron incorporation in the plaster is to permit ambulation on the injured leg for its circulatory good, to prevent extreme muscle atrophy, and to permit activity without putting lateral or axial stress on the healing bone or bones. This makes convalescence shorter and happier and, when all restraint is removed, there is less circulatory disturbance and a more rapid return to full function of the leg. Its use then should not be encouraged until the bone is well advanced in its healing and its character is largely protective against lateral strain. It may come far from by-passing the fracture site to protect against direct weight bearing. It must be inspected at frequent intervals and kept taut around its top.

After removal of supporting plaster splints from legs of elderly people, overweight persons or careless children, the wearing of an articulated-at-the-ankle double side iron from below the knee into the heel of the shoe must be demanded as a guard against secondary angulation and accident leading to refracture.

Leg fractures cannot be hurried in their final healing. The time required varies from four to six months or even longer. There may be circulatory stasis, aseptic necrosis of intermediate fragments or some pain persisting for additional weeks, finally yielding to carefully graduated increased use with good local supporting shoes and leg massage not too vigorous in character. It will be found, when a large series is studied, that the cardinal aims of full length and complete axial restoration are not attained in over 75 per cent of these accidents.

THE TREATMENT OF COMPOUND FRACTURES OF THE HAND

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F.A.C.S.†

IN a recent issue of these Clinics¹ we discussed the management of open wounds of the hand and outlined the principles upon which such treatment is based. Brief reference was made to the management of compound fractures, particularly in certain crushing injuries and in wounds associated with loss of covering tissues. The presence of fractures in the compound wound often poses a real problem to the surgeon since their reduction and maintenance in reduction often renders difficult other measures such as closure and compression dressings. This is especially true if traction is used to maintain position since it is almost impossible to keep the hand in the position of function and, at the same time, to apply a compression dressing to hold skin grafts in place, minimize edema and promote healing.

General Measures.—The wound with a compound fracture should receive the same general care as any other open wound of the hand. As first aid it is covered at once with a sterile protective dressing, a splint is applied and the patient sent at once to a hospital for definitive care. There, following brief inspection of the injury under aseptic precautions and surgical masking, a careful history is taken, diagnosis of extent of the lesion is made and roentgenograms taken to demonstrate bony damage. The situation is carefully evaluated both as to the local situation in the wound and the general condition of the patient. Time and circumstances surrounding the injury are ascertained as well as the nature of the first aid and any other treatment that may have been given with the idea of assessing the possibility of serious secondary contamination. The data obtained enable the surgeon to gauge the extent to which primary care may be carried out in his initial treatment of the injury.

Cleansing and Excision of the Wound.—Transformation of the "dirty" wound into a clean surgical wound is carried out in the operating room with soap and water, following which all devitalized tissue is removed by sharp dissection.

The greatest of conservatism is to be practiced in the removal of bone fragments in cases of compound fractures; every viable and potentially useful fragment of tissue should be left. Bone fragments and chips entirely devoid of connection with surrounding periosteum or soft tissues must be removed but if any connection, even the slimmest, is present, that fragment is left to be molded into position when reposition is done.

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Tendon and Nerve Repair.—The presence of compound fractures may alter somewhat the surgeon's decision as to tendon repair. Reduction of fractures must take precedence if there is a choice of one or the other. For example, a divided tendon at the site of a compound fracture is ordinarily not repaired primarily since its healing callus would become adherent to the bone callus and also because the position needed to maintain bone reduction would, in most instances, be inimical to the position necessary for relaxation of the sutured tendon.

Nerves, on the other hand, may be sutured whether a fracture is present or not, other conditions permitting.

Closure of the Wound.—Following deep repair and fracture reduction, closure of the wound is indicated. Suture is preferable to the use of skin grafts but these valuable adjuncts must be freely used if indicated. Free grafts of the split-thickness variety are the most often indicated; only occasionally must the surgeon have recourse to pedicled flaps.

The presence of fractures often complicates closure of the wound. It may happen that the loss or necessary excision of nonviable skin may leave the fracture site exposed. This complicates the problem since free grafts will not take on exposed bone, particularly at the site of fracture, and the use of pedicled flaps makes fracture reduction very difficult. The surgeon must not be tempted to save skin that he would otherwise excise in order to cover over a compound fracture site. Such a maneuver will not save devitalized skin and the fractured bone beneath will probably become necrotic as well. There are several alternatives in situations of this sort. It is often possible, by shifting adjacent skin, to cover the bone with a flap of sound skin and subcutaneous tissues, while a split-skin graft is placed over the area from which the flap was shifted. Occasionally adjacent soft tissues are available which can be shifted over the fracture site. If so, split-skin grafts may be laid over the area thus protected. In an occasional instance salvaging of the hand will demand the use of a pedunculated or pocket flap. This is the least desirable solution since it is then very difficult to manage the fractures.

Compression Dressing.—The use of a compression dressing following surgical intervention often makes the difference between success and failure of a skillful operation. Success not only in immediate healing, but late success from the standpoint of function since the edema and swelling which follow compound injuries, particularly the crushing type with fractures, may lead to so much fibrosis and stiffening as to compromise use seriously.

It is right here that one comes up against one of the real problems of compound fractures of the hand. This is the need for a compression dressing while maintaining the fracture in reduction. If traction is applied to hold reduction, compression is difficult or impossible to maintain, while, if a compression dressing is put on, reduction is difficult to hold.

Splints.—Following operation a splint is applied not only to hold fractures in reduction but to put the tissues at rest during the process of healing. Here, again, the presence of fractures poses a problem since we

wish to immobilize the hand if possible in the position of function. Certainly those wounds associated with compound fracture are usually crushed and severely lacerated and if the hand is allowed to heal in a bad position subsequent restoration to use is extremely difficult. Hence, if we can immobilize in the position of function, so much the better.

To meet these two latter indications in the treatment of compound injuries and fractures of the hand we have sought some method whereby fractures could be reduced and held in reduction with the hand in the position of function in a compression dressing. In order to accomplish this we have attempted to develop a splint which would fit the hand smoothly and evenly, holding it in the grasping position and permitting even pressure to be applied to it, and at the same time permit and maintain reduction of fractures.

We have described this splint elsewhere² and do not wish to repeat the description in detail here. It is rather simply though exactly made of aluminum so fashioned that either the right or left hand falls upon it in the position of function. It is constructed so as to fit the hand smoothly so that the pressure of a compression dressing is evenly distributed and pressure areas do not develop. In using this apparatus we have not found it necessary to use traction in holding reduction. As a matter of fact, when we first started to use the apparatus we made preparations for applying traction, but never found it necessary to use it. While we do not claim that every fracture of the hand can be successfully treated on this apparatus (universal hand splint), the great majority can be so treated. We wish, however, not to advocate any particular type of splint or apparatus, but rather to emphasize the principles which we have tried to follow and the indications we have tried to meet in caring for open fractures: reduction of the fractures with the hand splinted in the position of function under a compression dressing.

ILLUSTRATIVE CASES

The following cases will illustrate the different types of compound fractures of the hand and problems connected with them in a group of patients cared for during the past few years.

CASE I (Fig. 5, R. N., Hosp. No. 93687).—This 28 year old construction worker sustained a severe crushing injury when a heavy beam fell and struck his left hand. First aid consisted only of wrapping the hand in sterile gauze, and the patient was transferred to Passavant Memorial Hospital within forty-five minutes after the injury.

There was no sign of shock on admission. A superficial examination revealed obvious deformities of the index, middle, ring and little fingers. Sensation on the radial side of the index finger was absent, but motion was not attempted because of the obvious fractures. The patient was prepared for a general anesthetic, and on the way to the operating room an x-ray was taken of the hand. This examination confirmed the diagnosis of fractures of the proximal phalanges of the second, third, fourth and fifth digits with severe comminution and with the fracture line extending into the metacarpophalangeal joint of the fifth finger.

The suture was placed through the nail at surgery in case traction should be required to reduce this difficult fracture. It has been so rarely necessary to apply traction since we have used the universal splint that we have practically given up the practice of preparing for traction at the time of the initial operation.

The extensor tendon and the digital nerve were repaired at the time of primary surgery. The extensor tendons can often be repaired with a fair chance of successful end result in these severely comminuted fractures of the phalanges. Flexor tendons on the other hand when divided at the site of a compound fracture are usually best not repaired. The extensive dissection required to uncover them and the difficulties in maintaining relaxation render repair a rather formidable procedure. The difficulties or impossibility of maintaining relaxation after repair and the certainty of adhesions between the bone and tendon callus usually vitiate any repair performed. However, in this case the accurately reduced comminuted fractures did not fuse with the extensor tendons to interfere with final motion of the digits and a satisfactorily functioning hand resulted. Ordinarily the bone and callus will unite with the extensor tendons and prevent final motion. However, this complication occurs more frequently when accurate reduction is not obtained.

Here then was a case with severe fractures of the proximal phalanges, with injury to the digital sheaths and division of the extensor tendon. The splint allowed proper reduction and alignment of the fractures, aided in reducing the postoperative swelling and permitted satisfactory repair of the extensor tendon.

CASE II (Fig. 6, M.S., Hosp. No. 94424) —On December 17, 1946 this patient received a severe injury to her left hand while operating a punch press. She was seen one hour after the injury. Examination of the hand with x-rays revealed a severe crushing type of injury. The fourth digit was dusky and it was carefully explained to the patient that amputation might have to be done but she begged that this digit be preserved if possible. Under these circumstances every attempt was made to save this finger.

After careful cleansing in the operating room under general anesthesia the hand was examined more critically and the following extent of damage was determined. There was a fracture of the second metacarpal with extreme comminution and marked displacement. There were comminuted fractures through the distal and proximal end of the proximal phalanx of the ring finger, and a transverse fracture through the distal phalanx of the same digit. A comminuted fracture of the proximal phalanx of the little finger was also present. There was a circular loss of skin about 1½ inches in diameter on the palmar surface and a long jagged laceration of the palm extending over the ulnar side of the hand and continuing to the dorsal surfaces of the ring and little fingers. The extensor tendon of the little finger had been divided as was the extensor tendon of the ring finger which had been divided in places at the level corresponding to the double fracture of the proximal phalanx of this digit. The ulnar nerve was intact but found to be suffused with blood throughout its entire course in the wound. There was a laceration over the web space between the thumb and index finger on the dorsal surface

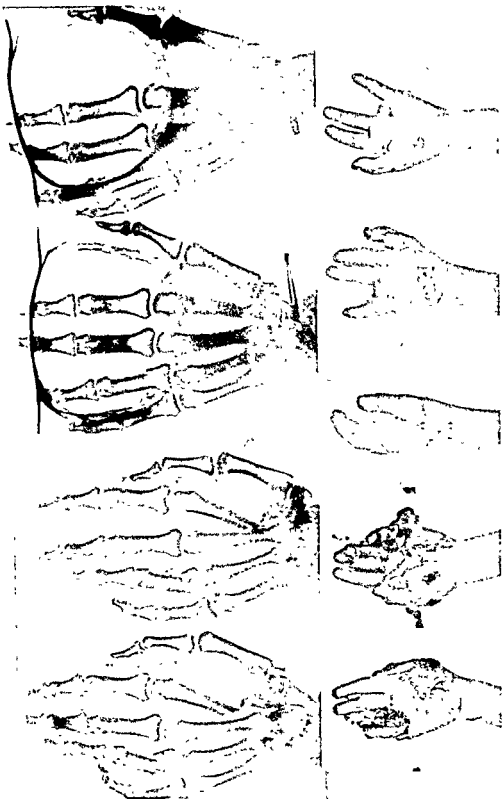


Fig. 6 (Case II)—Severe punch-press injury of the left hand with multiple fractures, division of the extensor tendons to ring and little fingers, crushed muscle and torn and avulsed skin. The upper row shows the pre- and postoperative x-rays. The lower row shows the preoperative condition and result twenty-eight days postoperatively.

through which protruded the badly contused and devitalized first dorsal interosseous muscle

After careful excision of all obviously nonviable tissue—muscles, the skin edges, subcutaneous tissues—the extensor tendons were repaired and the wound closed in layers. The circular defect on the palm was closed with a split-thickness skin graft. The fractures were reduced and their reduction maintained over a padded sterile universal splint by the use of a voluminous pressure dressing. The color of the ring finger was of great concern throughout the operation and no great hope was held for its eventual survival. Postoperatively its dusky color slowly increased and by the third postoperative day the digit was obviously gangrenous. This finger was amputated at the level of the web ten days postoperatively.

The x-rays taken after surgery revealed satisfactory reduction of the various fractures. The soft tissue wounds healed satisfactorily and the thin skin graft took completely over the palmar defect.

This represents a serious type of injury involving multiple fractures, divided extensor tendons, muscle damage, crushed torn skin and actual skin loss. The universal splint permitted accurate reduction of all of the fractures and even that of the proximal phalanx of the ring finger which was fractured at two sites. The skin graft and the soft tissue wounds healed without infection. Postoperative swelling was kept at a minimum by the pressure dressings and the accurate reduction of the fractures. The ring finger was of doubtful viability when first seen but upon critical examination in the operating room it appeared that the digit might possibly survive. Undoubtedly we were influenced somewhat by the patient's great concern over losing the finger. However, later amputation at the level of the web was performed when the first dressing revealed the exact level of dry gangrene. Fortunately infection did not occur.

CASE II. (Fig. 7, M. W., Hosp. No. 89269) —While operating a punch press this 20 year old patient received a severe injury to his right hand. He was transferred to Passavant Hospital where superficial examination revealed multiple compound fractures of the hand. There was no shock and the patient was quickly prepared for general anesthesia and on the way to the operating room x-rays were taken of the hand.

The hand was carefully cleansed under general anesthesia and the wound critically inspected. It was found that there were multiple fractures involving the bases of all of the metacarpals and the distal row of carpal bones. There was also a compound dislocation of the interphalangeal joint of the thumb. There was a bursting laceration at the dorsal web space between the thumb and index finger through which protruded the obviously devitalized muscles of the first dorsal interosseus. There was division of the extensor tendons of the fourth and fifth digits. It was necessary to excise most of the first dorsal interosseus muscle which was severely contused, but most of the dorsal skin appeared satisfactory to a critical appraisal at the time. After excision of the obviously devitalized tissue all the structures were repaired, the joint capsule of the thumb was closed and the extensor tendons to the fourth and fifth digits were sutured and the open wounds were closed in layers. The hand was immobilized over a padded sterile splint. The positions of the

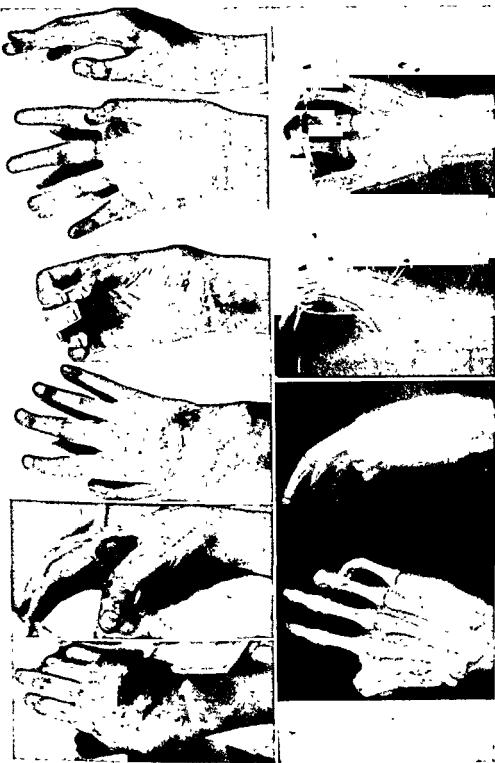


Fig. 7 (Case III) — Punch-press injury to right hand with multiple fractures of the thumb, all of the metacarpals and the distal row of carpal bones, with division of the extensor tendons to the fourth and fifth digits. The upper row shows the condition of the hand preoperatively and six weeks postoperatively. Note the adduction of the thumb because of the injury to the web space. The reduction of the fractures shows the adaptability of the unvul-
sal splint for both carpal and metacarpal fractures

what appeared to be crushed burned skin and leaving a defect 6 by 8 cm. The proximal and distal stumps of the communis extensor to the index were sutured to the sides of the extensor indicis proprius tendon and the stump of the tendon of the third digit were similarly sutured to the sides of the communis extensor of the ring finger. The wound was closed with interrupted sutures and the hand was then molded over a sterile padded splint. A pressure dressing applied. The graft healed and the fractured metacarpals were maintained in satisfactory position by the use of a splint.

This represents the type of crushing injury where skin, subcutaneous tissue, tendons and bones are all involved. To obtain satisfactory healing the excision had to be complete and sufficiently wide to reach healthy bleeding skin and subcutaneous tissues. The blood pressure cuff was not used in this case except to test for the extent of vascularity by elevating the pressure for about three minutes and then releasing it to gain some opinion of the area of viable skin from the resulting hyperemia.

The divided extensor tendons were simply sutured side by side to adjacent intact tendons, and then the exposed tendons and bone were carefully covered with shifted areolar and subcutaneous tissues. The entire wound was dressed with skin to accomplish complete closure of the area. Tie-over sutures were used to hold the pressure dressing in satisfactory position. The splint held the hand in an adequate position for healing of the sutured tendons, the fractures and the skin graft. The extensor of the index finger has healed in a slightly relaxed position and fails to completely extend this digit. However, this case illustrates again the adaptability of the splint in that it may be used for skin grafting, tendon suture and handling of the fractured bones by maintaining the hand in a position of function.

CASE V (Fig 9, V J, Hosp No 101557) —Three days before admission to the hospital this patient had sustained a compound fracture to the right second and third metacarpals when a heavy door struck the dorsum of the hand. Her physician closed the wound under local anesthesia and x-rays taken later revealed comminuted fractures of the bones with considerable displacement. When this patient was first seen at Passavant Hospital the wound was briefly examined and the hand placed on a universal splint. Four days later, seven days after the accident, a secondary reduction and closure was performed. At operation there was found no evidence of infection and the sutures were removed. A large hematoma deep in the wound was evacuated and the fractures were reduced under direct vision. There was no internal fixation of the fractures. The hand was placed on a sterile padded universal splint and a satisfactory reduction of the fractures maintained while the skin and subcutaneous tissues were closed. A large pressure dressing was then applied. Postoperative films revealed all fragments to be in satisfactory condition except for a small piece of bone 6 mm. by 4 mm. between the second and third metacarpals. This was removed six months later.

This case is an example of the delayed reduction of the fractures, the method of care corresponding somewhat to that given to compound hand injuries during World War II. The optimum time for accurate delayed reduction appears to be within five to seven days after injury before fixation has occurred. The hematoma deep in the hand gives some clue to the pathology of the late swelling, edema and fibrous fixation which is the bugbear of crushing injuries to the hand. Fairly complete defini-

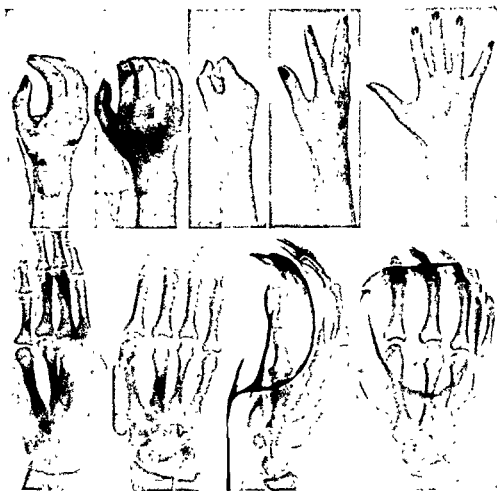


Fig. 9 (Case V).—Delayed reduction of severely comminuted displaced fractures of the second and third metacarpals. The photographs show the condition of the hand at the time of the first postoperative dressing and the function of the hand ten weeks later. The x-rays illustrate the reduction obtained, and the maintenance in that position on the universal splint.

tive care with attention to control of all bleeding and accurate reduction of the fractures are important in minimizing the development of thickened swollen hands which are so typical of these injuries.

The universal splint allowed accurate alignment of the fractures under vision without internal fixation and the position was held firmly by the

MANAGEMENT OF INTRACAPSULAR HIP FRACTURES

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IN December, 1943, I presented a paper in which I attempted to standardize criteria for adequate reduction of a femoral neck fracture. This paper was published in 1945¹. Since that time, continued observation and study have strengthened the original contentions.

ROUTINE MANAGEMENT

The care and management of the patient in the hospital often determine the outcome of the individual case. The care given a premature infant by the nurses and house officers in the hospital probably outweighs most other factors in determining the fate of the individual child. Elderly people resemble premature infants in their response to nursing and medical care. Good care means low mortality; bad care means high mortality.

It must be definitely and emphatically stated that an intracapsular fracture of a femoral neck in an elderly patient is no surgical emergency, but may well be a *medical* emergency.

The patient is put in a bed with boards beneath the mattress. Russell traction, with no more than 5 pounds of weight, is applied to the affected limb. The foot of the bed is elevated one or two notches. The rubber sheet is taken from under the drawsheet and placed next to the mattress, so as to allow for a mattress pad and two sheets between the rubber and the patient's buttocks. A fluffy pad is placed between the patient's buttocks and the sheets. This prevents steaming and excoriation of the involuntary patient in her own excreta. A complete overhead frame with hand attachments is present. The patient is encouraged to move about, lift herself up, sit up, roll, and in all ways keep moving. An elderly patient in good or fair condition, who is correctly tractioned and cared for, is comfortable. She can and will follow the above orders.

The patient is turned from back to side every two hours by the nurses. If it is not insisted upon that the patient turn herself or be turned every two hours, the floor care becomes desultory. Nurses can observe and remedy early trouble if the patient turns. Under this treatment, bed sores will not develop. The usual medication is an initial dose of $1\frac{1}{2}$ grain of morphine, and later dosages of 1 grain of codeine, and 10 grains of aspirin by mouth.

An elderly patient who is in pain, who is in faulty traction or no traction, who is in a wet bed, and who is generally miserable, usually gets

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poor nursing care and frequent hypodermics. She is first, demoralized, second, disoriented, and third, dead.

The medical care of the individual concerns itself with a complete survey of the vital functions and systems. The heart, chest, blood, liver and kidneys are checked, and the medical care is aimed at putting the patient in balance to withstand surgery. Surgical intervention is postponed until this balance has been attained. The average time from admission to operation is seven to ten days. Often the time is longer; seldom, if ever, is it shorter. In our opinion, it is foolhardy to operate on a patient who is in poor condition only in order that she may be gotten out of bed. We may err in this respect, but we do not believe we have ever saved a life by operating because of the poor physical condition a patient is in. Rather, we feel that if she is comfortable, her best chance lies in good medical preparation first and good surgery later. Under this regimen we feel that if the patient is going to rally, she will. If she is not going to, or if her condition otherwise is such that it precludes use of a good hip, futile surgery has been avoided. An interesting observation that appears to check with a patient's ability to withstand surgery is her ability to hold her breath. If a patient can hold her breath fifteen seconds by the clock, she is likely to be a fairly safe risk. If she can hold her breath twenty-five seconds, she is likely to be a good risk.

Preoperative Care.—The night before the operation the patient is typed, and two pints of blood are obtained for her. The affected side is prepared from nipple line to just below the knee and to the midline of the abdomen. After the parts have been shaved, they are cleaned with cotton pledgets dipped in soap and water, washed with alcohol, and dried with ether. Sterile towels are placed over the area in overlap position and firmly bound with gauze bandage, which in turn is held in place with spiral adhesive.

The patient is left in traction, and the adhesive and foot block are left on. If the adhesive extends above the knee at the time of preparation, it is stripped to below the knee. The patient goes to operation with this intact, and when she is returned to bed she is placed immediately in 4 to 5 pounds Buck's extension with the same block and adhesive.

Postoperative Care.—After operation the patient receives no more than one hypodermic of $\frac{1}{2}$ grain of morphine. Codeine is given hypodermically for pain after the initial dose of morphine, and later on, codeine and aspirin by mouth are given when necessary for relief of pain. Penicillin is given routinely.

No attempt is made to hurry the patient out of bed. Good bed care is as effective as the use of a wheel chair. The patient usually asks to get up, or is in condition to do so, from ten days to three weeks after operation. In the meantime, she is rehearsing her deep-breathing exercises, her many turning and lifting movements, and her leg movements of flexing, exercising the foot, and the likes. She is allowed up in the chair first, taught to use crutches later, and allowed to bear weight ac-

cording to individual conditions. Usually, weight bearing begins from four to six months postoperatively. No braces or calipers are used. Frequent x-ray check is insisted upon.

PROCEDURE OF OPERATION

The development of the actual procedure in the operating room follows. The two most important factors to be considered in the operating room are first, the anesthesia, and second, the x-ray.

Ordinarily, we do not use spinal anesthesia in the elderly person. The correct performance of the complete procedure from the beginning of the anesthesia until the time when the patient is returned to her room usually requires from one to two hours. Spinal anesthesia has variable and unpredictable side effects. Many patients become excited and apprehensive, and at times the anesthesia wears off prior to completion of the procedure.

Local anesthesia has all the disadvantages of spinal anesthesia, plus poor relaxation, and lack of anesthesia about the foot, ankle, and knee.

We have found the most satisfactory anesthesia for the patient and the surgeon to be a pentothal induction followed by inhalation anesthesia composed of 50 per cent nitrous oxide and 50 per cent oxygen, with occasional, small additional injections of pentothal.

Statistics reviewed by us show the highest mortality following hip surgery in elderly patients occurs in cases receiving local anesthesia, spinal anesthesia, and nitrous oxide in concentrations above 70 per cent. The lowest mortality occurs in those receiving pentothal with nitrous oxide and oxygen. Only under the most unusual conditions will our anesthesia department vary from the routine anesthesia as set forth above.

If the patient is in any pain, the anesthesia is started with the patient on the cart, and she is then lifted to the fracture table. When the patient is on the fracture table and asleep, she is placed on the cassette holder of the table with the narrow perineal post in place. No saddle is used, as the cassette box is supporting the patient throughout the procedure. Both feet are securely lashed to the foot pieces, and traction is applied equally to both lower extremities, so that when heavy traction is applied to the affected limb, the patient will not shift from her position against the well-padded perineal post. Blood infusion and other intravenous fluids are now started.

If one has an x-ray head attachment, it is now fitted into position on the table (Fig. 11). If not, the normal limb is lowered by dropping the foot-piece post, the limb is placed in some abduction, and a portable x-ray machine is moved into position as close as possible to the groin on the affected side. After this another portable machine is moved over the affected hip, for taking the anteroposterior view. The x-ray technician now measures the part, makes the necessary calculations, and sets the machines. The operator proceeds with the reduction. X-rays in both anteroposterior and lateral views are now taken. An assistant starts

scrubbing up, and the surgeon waits to view the wet plates to see whether or not reduction has been accomplished and whether or not the x-rays are of diagnostic value. *So important are these two factors to both the patient and the operator that no draping or removal of drapes is allowed until the reduction in abduction has been achieved, and the x-ray technician has adjusted her machines to the point of getting diagnostic, clear-cut, well-centered films, showing complete head and neck in both lateral and anteroposterior views.* When this objective has been accomplished, and all settings

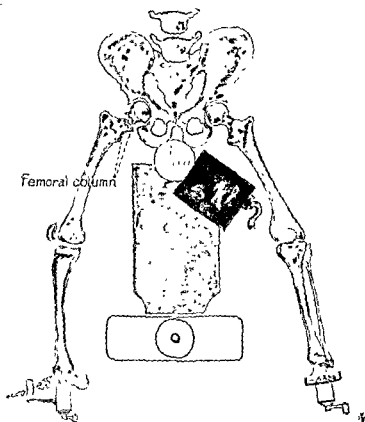


Fig 11 —Diagram of table set-up with x-ray head. Extremity is in complete external rotation with traction applied and neck shifted medially

are in order, the surgeon adducts the limb and has x-rays taken in both anteroposterior and lateral views. If these films are satisfactory, he then checks all fittings on the table to see that no motion of the patient or of the limb can occur. Then, while the surgeon scrubs up, his assistant drapes the table and patient. A marker, such as a towel clip, is placed either over the affected hip where the center of its head should be, or, as we prefer, over the opposite anterior superior spine with the pelvis level.

A longitudinal, lateral incision, centering the greater trochanter, is

started just below the upper border of this structure, which is palpable because of the complete internal rotation, and is carried down the thigh about 6 or 7 inches. The fascia lata is reached, but not cut until the overlying fat has been dissected from the fascia to expose this latter structure in a strip about 1 inch wide. Then the lower limit of the fascia is nicked with a knife, a curved Pean inserted as a guide between the fascia and the vastus lateralis muscle, and the fascia opened in a longitudinal direction up to the trochanter. This clearly exposes the attachment of the vastus lateralis at the base of the greater trochanter. This is cut through transversely in its fibrous portion, leaving enough fibrous attachment on the trochanter for re-attachment. With a broad periosteal elevator, the vastus is scraped distally to expose about 3 inches of the shaft directly beneath the greater trochanter.

Following this, a $\frac{1}{4}$ -inch drill hole is started $1\frac{1}{2}$ to 2 inches below the lower border of the greater trochanter, centering the shaft. The drill is started at right angles to the shaft, but as it bites its way through the outer cortex, the point is directed toward the marker on the opposite anterior superior spine, while the drill is kept level with the plane of the ground. The drill is continued into the neck for a depth of about two inches and then withdrawn. A $\frac{3}{8}$ inch Kirschner wire is then placed in the drill hole and lined up with the marker on the opposite spine and parallel with the ground. The operator then elevates his hand about 5 degrees so that the point of the wire slants slightly toward the ground and in line with the marker. The wire is then gradually thrust home by hand until firm resistance is met. Two or three light taps with a hammer set the wire. X-rays are again taken. If the wire is perfectly centered in both lateral and anteroposterior views, the depth is judged and adjusted to proper standards—a depth taking at least three quarters of the head, but missing the periphery by at least $\frac{1}{4}$ of an inch. This is checked by x-ray.

When the wire is in satisfactory position, an identical wire is placed alongside the first wire until the point of the second touches the femoral shaft. The difference in the length of the wires outside the femur shows the length of wire in the femur, and one can thus judge the length of the cannulated nail required. If the first wire is not perfectly centered in both planes, a second wire is attached to a drill. After a study of the x-rays showing the first wire, it is usually quite easy for one to angulate the second wire in such a way as to center the head and neck perfectly in both planes and get proper depth. The $\frac{1}{4}$ inch hole in the femur gives sufficient room to allow one to do this carefully and well. The wire is thrust home and only drilled when resistance is met. After the nail length is determined, the wire may be drilled into the acetabulum under x-ray control, if such action is deemed advisable.

A starter is placed over the wire and held on the wire in such a way that it will not angulate against the wire, for this will mar or cut the wire. The cortex is first cut with the starter; then the starter is rotated one-quarter turn and the cortex is cut again. This process is continued until

most resistance of the cortex is broken. This starts the nail easily, prevents the edges of the nail from being turned, and precludes the tendency for the nail to push the head away.

The starter is removed, and the nail is threaded over the wire. Great care must be exercised to avoid angulating the nail or the wire. If angu-

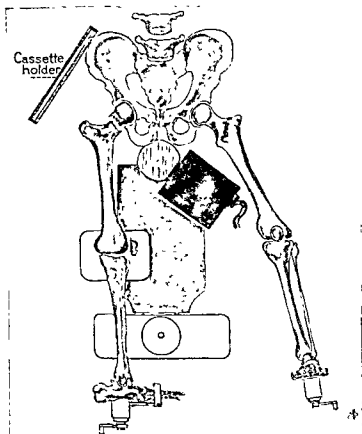


Fig. 12—Illustrating position of extremity for fixation of hip fracture. Note

lation should occur, the wire will be carried ahead of the nail and may bend or enter the pelvis. These are preventable complications.

The nail should enter the shaft and neck easily. As the nail enters the head, slight resistance to the light taps of the hammer can be felt, and the tone of the hammer against the driver assumes a higher, less hollow sound. If any hard hammering is necessary, or if resistance is felt, one or both of the following things should be done.

First, the driver should be unscrewed from the nail and the length of

the wire measured with the wire which was previously marked for depth. If the wire is following the nail, a drill should be placed on the wire and the wire pulled out about an inch. The nail should be started again, and if it goes easily, one or two x-rays in the anteroposterior view can check correct position of the wire as the nail goes home.

Secondly, if resistance is still met, an x-ray in both views should be taken. If x-ray reveals bending of the wire ahead of the nail, the wire should be taken out by means of the drill. Fortunately, by the time this occurs, if it does, the nail is so deep that its course is determined. Since the length of nail is known, another wire can be quickly placed through the nail and put to proper depth. If the wire is so badly bent that it will not return through the nail, the nail must be carefully tapped out and the wire removed. The nail should then be replaced and another wire put through the nail to proper depth. Again an x-ray check is made, and if the position is satisfactory, the nail is driven home.

Before the final setting of the nail, an x-ray is taken when about $\frac{1}{2}$ inch of the nail protrudes from the femoral shaft. If length is correct, the nail is driven home to the head, but no deeper, or splitting of the shaft may occur. If the nail is either too short or too long, it is changed before being set.

The final position of the nail is checked in both planes by x-ray, and the wire is removed. The heavy traction is released, the wound is irrigated with four quarts of warm, sterile saline, and the wound is closed.

GENERAL CONSIDERATIONS

In many cases of hip fracture in elderly adults, there is a history of trauma. The majority of these fractures, however, occur in women, and the initiating cause is almost impossible to elicit. Close questioning of patients and relatives often gives no real clue to what happened to initiate these fractures. We call these common fractures "idiopathic." By this term is meant that no real factor, such as tumor or adequate trauma, can be used to explain the fracture. It is our opinion that these idiopathic neck fractures should be classed as march, fatigue, or insufficiency fractures.^{1, 2}

In any discussion of bone healing, one must differentiate between immediate union of broken bone and the later process of revitalization of bone. These two processes blend into one another. The first precedes the second; the second usually follows the first. In certain anatomical locations, such as the hip or the talus, revitalization may not occur soon enough, may be only partial, or may not ensue.

Large grafts, for all practical purposes, are dead bone. Grafts correctly applied usually take. Immediate union of dead bone to living bone thus occurs at the contact areas of the graft and the host. The graft, if bridging a defect and thus receiving forces upon it, must be protected for months until revascularization is complete.

Thus, it can be deduced that lack of blood supply to the graft has

little effect on the immediate union of the graft to its host, but has a great effect on the ultimate fate and function of a graft that has great forces working on it, either because it bridges a defect or bears unusually severe weight or functional forces.

This paper deals with the immediate union of the graft (the femoral head) to the host (the femoral neck) at the fracture site. It does not deal with the ultimate fate of the femoral head, which, if deprived of complete blood supply at time of fracture, may resemble a large bone graft. The complete revitalization of a femoral head after solid union at the fracture site takes many months, even years.

We routinely keep our hip patients four to six months before allowing weight bearing. The older the patient, the sooner weight bearing is allowed, because of the fewer remaining years of service the hip must endure. Three of our patients (one through a misunderstanding, and the other two through complete disregard of instructions) began bearing weight between four and seven weeks postoperatively, and were going about shopping twelve to fourteen weeks after pinning, with no support except a cane. They experienced little pain, some limp, and moderate swelling, with a feeling of aching fatigue of the whole limb if used hard. One hip of this series is five years post-pinning, another is fourteen months, and the third is eight months. So far, these hips, by standards of x-ray and function, compare favorably with excellent hips that have not been allowed to bear weight for six months.

The process of complete revitalization of a femoral head sufficient to withstand the onslaughts of function, according to our viewpoint, takes more than six months. We feel that a correctly reduced and pinned hip, that shows every evidence of being healed at ten to twelve weeks, will withstand full weight bearing. Those in the older age group may well begin walking with a cane at this stage. Patients in the younger age group should delay full weight bearing for many months. Whether or not this long period of waiting diminishes the effect of aseptic necrosis or arthritic changes in heads deprived of blood supply at time of fracture is not yet known in this condition.

We feel, also, that the six months' period of non-weight-bearing has no relationship to the time required for complete revitalization of a femoral head. Rather, we feel that this stipulation of a six-months' time interval developed in the day when reductions were uniformly poor, and fibrous union at the fracture site was commonplace. Experience at that time probably pointed to six months as the average time when fibrosis about the hip was strong enough to withstand, partially at least, full weight thrust.

Rapid union in a hip gives every advantage to the patient. Clinically, patients who are going to have good hips, with true immediate union at the fracture site, are well on their way toward this end by five weeks after fixation. Patients who are going to have fibrous union ("molten flowing"), ultimately ending in bony union, or who are going to have no bony union at all, at no time handle the leg well following fixation. Lack of full

internal rotation and lack of full, active control of the limb are seen early in these cases. Limp, groin pain, and a desire for external support, such as a cane, are present in all of these cases in varied degrees. From the time of fixation on, these failures never do get along well (Figs. 15, 23, 26).

A patient with a well-united hip has at least a few years of active, normal life in view with no limp, pain or spasm. She uses no external support to walk or climb. She has full, active control of the limb and practically complete internal rotation. She returns to her former mode of living (Figs. 20, 22, 25).

REDUCTION

The purpose of this paper is to describe a method of reduction whereby I feel, from my experience and from confirmation by others, the chance of immediate bony union is greatly enhanced. When the reduction to be described is obtained, the chances of union are as good as, if not better than, any form of immediate osteotomy we have used. Furthermore, the gait and use of the limb are better, and the fate of the femoral head seems no more insecure than when an immediate osteotomy is done.

The Criteria of Reduction.—It has long been recognized that certain so-called impacted femoral neck fractures will support full weight bearing and heal without fixation. Others, appearing also to be impacted, readily disengage and fall apart under similar circumstances. The former may be called true *abduction* fractures, and the latter, false abduction, but true *adduction* fractures (Figs. 15, 20, 21).

An abduction fracture, by our definition, is one in which a force is exerted in such a manner as might occur with the legs spread. The force on the upper femur is directed downward and medially. This causes the upper portion of the femoral shaft and neck to shift downward and medially. The result is that the femoral head is thrown toward valgus, and the inner (medial) portion of the neck fragment comes to lie inside the medial portion of the head fragment.

An adduction fracture, then, is one in which the force exerted on the upper end and neck of the femur is produced by adduction of the femoral shaft, and consequently shifts the upper end of the femur and neck in an upward and outward direction. The result is that the femoral neck tends to go upward and lateral to the head, spinning the head toward varus, and shifting the inner (medial) portion of the neck fragment slightly above and to the outside of the medial portion of the head fragment (Figs. 13, 14, 15, 16).

All disengaged hips are considered adduction-type fractures. Many so-called impacted fractures are adduction-type fractures also, and will fall apart if not fixed, or fail if internal fixation is used without further reduction.

One should attempt to convert all adduction-type fractures, whether impacted or not, to abduction-type fractures at the time of reduction.

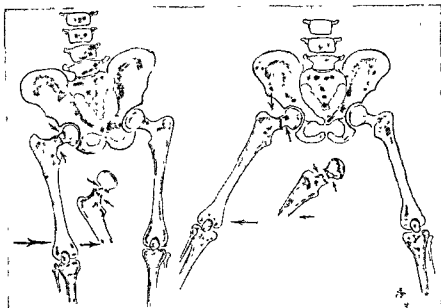


Fig. 13 —Illustrates diagrammatically one method by which adduction fracture (*left*) and abduction fracture (*right*) might occur.



Fig. 14 —Specimen of intracapsular fracture of two weeks' duration obtained at necropsy. Never reduced or internally fixed. *A*, Illustrates adduction (under-reduced) type of reduction. *B*, Illustrates abduction (over-reduced) type of re-

This is possible with but few exceptions. An abduction-type fracture, according to our conception, is considered gained when the medial portion of the neck fragment (femoral column) is under and inside (medial to) the inner portion (femoral column) of the head fragment (Figs. 12,

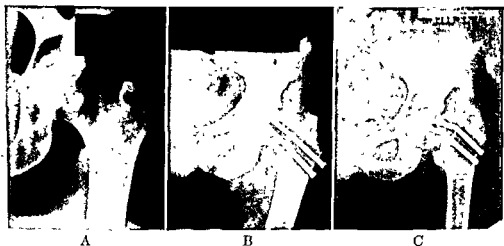


Fig. 15.—A, Spot film showing typical varus and adduction (under-reduced) type of hip fracture. B, C, Same illustrated.

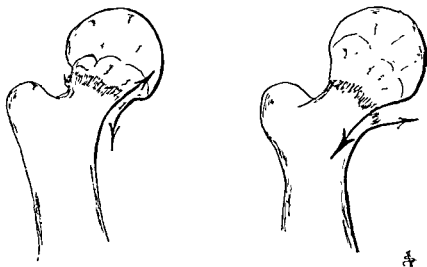


Fig. 16.—Illustrates method of testing on the spot film in the operating room whether reduction is adequate (abduction type), as shown on right, or inadequate (adduction type), as shown on left. If, as shown on the left, the neck line lies outside the head line even a millimeter or two, failure is probable. The neck line must, without doubt, fall inside the head line at least a sixteenth of an inch on the film. An eighth of an inch is better.

14, 16). In our experience, once this position has been gained and the fracture correctly fixed, union proceeds at least as rapidly as in hips having immediate osteotomies. That is, union is established in from eight to twelve weeks.

So much has been written about the importance of reducing hips so

that the head fragment is in valgus, that many men think that once this position of valgus is obtained, the criteria for an adequate reduction have been satisfied. An abduction type of fracture obtained at time of reduction almost guarantees a head in valgus. However, valgus itself may or may not indicate a reduction which will lead to immediate bony union. A head in valgus with the *medial portion of the neck fragment under and inside the head fragment usually means immediate bony union. Contrasted to this, a head in valgus, with the neck fragment slightly above and its inner*

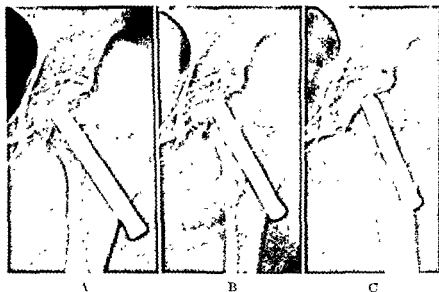


Fig 17—Three views of same hip, taken two months after pinning. A, Shows view in complete internal rotation. B, View in ten degrees of internal rotation. C, View in maximum external rotation.

Note that no lesser trochanter shows in complete internal rotation (A), and that this is only view showing without doubt that abduction (over-reduced) position of fragments exists. This view is only view containing definite diagnostic qualities, for determining accurately the relationship of head and neck at fracture site. (Compare with Figure 27, Series I and Series II.)

border slightly outside the inner border of the head fragment, usually means failure of immediate bony union (Figs 18, 23)

We can show cases in which an abduction type of reduction has been gained with the head in definite varus. These have all progressed to union and satisfactory hips. However, all of our cases in which varus of the head existed but the neck was not under and inside the head, as described, have failed to unite (Figs 15, 22).

We feel, therefore, that the terms "valgus" and "varus," as applied to the reduction of a fractured hip, are only relative and do not by themselves in any way imply any standard by which a reduction leading to rapid, immediate bony union can be judged. A hip united in valgus is



Fig 18—A, Illustrates inadequate reduction (adduction type) Note that insufficient traction has been applied, as shown by lack of distraction at outer side of head and neck, which prevents neck from moving under head. Note adducted position, with failure of neck to maintain desirable relationship to head. Fine lines have been drawn on this spot film, showing this clearly, yet fracture was pinned with nail centering neck and head in both planes. B, Shows result few weeks later. All strain and shearing forces have been applied from neck to metal, not from neck to head. Note "beak" on lower, inner portion of head fragment, that by over-reduction would have nestled inside projecting portion of femoral column on neck side, giving excellent chance for union. C, D, Show almost identical views in spot film and film a few weeks after pinning of hip having abduction type of reduction. Note how shaft in C and D appears to be under head and medially displaced, as compared to A and B. Compare with Figures 12 and 16

superior to one united in varus, but to us, obtaining valgus implies nothing except that good functional position is obtained if union occurs.

In this paper no mention will be made of an anatomical reduction. Anatomical reposition would mean that the inner border of the neck fragment (femoral column) would anatomically contact its counterpart (femoral column) on the inner border of the head fragment. In the x-ray view to be described here, there has been no case of absolute anatomical reposition observed by us in either our open or closed reductions. The



Fig. 19—Lateral view with wire satisfactorily placed, but not centered. When fracture is overpulled and internally rotated, as advocated here, lateral views

there, so that internal rotation is not complete, or it may throw the head fragment into a position of external rotation, and thus angulation occurs at the fracture site. Because of the spherical shape of the head, an anteroposterior x-ray view is of no value alone in judging nail depth, unless the nail is perfectly centered in both planes. If the nail is not perfectly centered, an anteroposterior view may show what appears to be satisfactory depth, while the lateral view may show the nail at the articular margin or beyond it. Final check-up before closing the wound should routinely include an excellent roentgenogram in both the anteroposterior and true lateral views.

femoral column of the neck fragment has either been just inside (abduction or over-reduced type) or just outside (adduction or under-reduced type) its counterpart in the head fragment (Figs. 14, 15, 20)

Technic of the Reduction.—This consists of converting an adduction

The reduction cannot be achieved routinely by manual traction or manipulation and should not be attempted.

A fracture table is used, and the patient is set up as previously described. The affected limb is placed in 20 to 25 degrees of abduction and in complete external rotation. Traction is gradually increased while the hip is gently toggled up and down. When sufficient pull has been made and the adductor muscles are taut, the foot piece is loosened to allow internal rotation. The foot should not be rotated to gain position, as great strain is sometimes put on the knee in this manner. Rather, the knee is rotated inwardly by the operator, while an assistant rotates the foot piece. If resistance of any degree is felt, the maneuver is not completed. More traction is made. The knee should internally rotate smoothly and with little effort. Internal rotation is continued until the



Fig. 20.—A, Illustrates complete internal rotation view, clearly showing what might be called anatomical reposition, but what closer observation clearly shows to be an adduction (under-reduced) type of fracture B, Illustrates effect of more abduction and traction, and of pushing medially against trochanter and then adducting shaft to about neutral. x-Rays shows fracture has definitely been converted to abduction (over-reduced) type and is now ready for internal fixation. C, Fifteen months post-pinning.

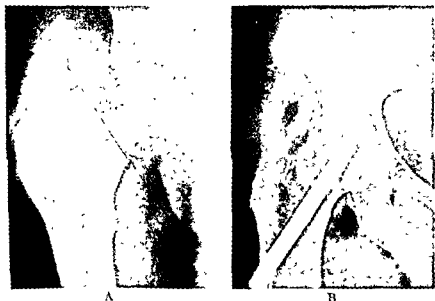
medial condyle of the femur points directly toward the floor and the patella faces directly medially. While this position is held, an x-ray in the anteroposterior direction is taken. If the x-ray shows the femoral column of the neck fragment to be under and inside that of the head fragment, the limb is adducted to neutral lateral position with internal rotation and traction maintained. If not, one judges from the x-ray whether or not more traction is needed to obtain enough overpull to allow the shaft under and inside the head. If more traction is needed, this is applied with the limb in more marked abduction than before and with internal rotation. With the increased traction maintained, one pushes downward and medially against the greater trochanter. The result of this maneuver is checked by x-ray. If reduction is satisfactory, one then adducts the limb to neutral, as described above (Figs. 11, 12, 18). Then anteroposterior



A

B

Fig. 21.—A, Illustrates impacted fracture. Internal rotation performed for this view without anesthetic. Internal rotation not quite complete, for fear of dislodging fragments. Careful observation reveals impacted adduction (under-reduced) type. B, Shows result after traction, abduction, and external rotation, followed by complete internal rotation, pushing medially against greater trochanter, and adducting limb. Fracture is now definitely abduction (over-reduced) type and is ready for fixation.



A

B

Fig. 22.—A, Shows hip with abduction type of reduction purposely pinned with head in varus. Angle is about 30 degrees. B, Result two years later.

and lateral x-rays are again taken. If, by adducting the limb, one has succeeded in keeping the fragments in position for locking, this will be

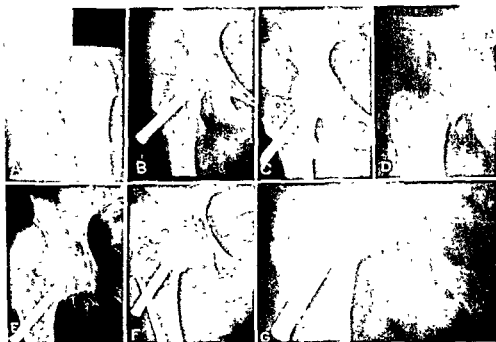


Fig. 23.—*A*, Illustrates inadequate reduction, that was converted into more of an abduction type before pinning. *B*, Shows results of this maneuver at six months post-pinning. *C*, Shows results at two years post-pinning. *D*, Another fracture showing inadequate reduction. The hip is still under-reduced and is of the adduction type. *E*, Same case, six months after pinning in position shown in *D*. Note projection of medial side of head in relation to neck. *F*, Same case two years post-pinning. *G*, Same case seven years post-pinning.

Fractures in *A* and *D* are similar in type. In contrasting position of shafts in *B* and *F* it appears that in *B* the shaft is in a more normal position.

D to *G* illustrate what we term "delayed union." At six months, *E* appears to be united, but at two years, *F*, the patient never was able to get up without a cane, and the like. Note in *F* how head has moved toward varus, and how productive bone reaction is marked on upper surface of neck, with fracture line and evidence of sclerosis showing. Patient had less pain three years after pinning than during first two years. Seven-year film (*G*) shows that bony union at fracture site finally occurred before nail cut out of head. Fibrocystic areas show in the sclerotic head, and are similar to areas about or in ununited or sclerosed carpal naviculars. We believe this condition should not be confused with true aseptic necrosis that follows true bony union. We feel that the etiology of these changes is the delayed union, and that if immediate bony union had occurred, these changes might have been prevented. Compare with Figure 25. Compare *G* with view without nail in Figure 25, *A*. Compare with Figure 26.

shown by the fact that the neck fragment remains under and inside the head fragment, with no slipping. The lateral view should show the fragments in line. Then, and only then, is fixation of the fracture accom-



Fig 21—Views of two hip cases, taken at thirteen months (A and D), five months (B and E), and at time of reduction (C and F). A, B and C illustrate a failure. Delayed union ("molten flowing") is evident in A at thirteen months. D, E and F show comparable views of hip with immediate union at fracture site. B above, and E below, show slight internal rotation, and the views are similar to x-ray views often used to judge reduction at time of fixation. In comparing the two, one can find no real diagnostic factors in either film, that indicate whether type of reduction is adequate or inadequate. They appear to be similar and might be interpreted as satisfactory reductions. C and F are spot films taken at time of reduction. These views, which are taken in complete internal rotation, show that C is inadequately reduced and should fail, while F is definitely an abduction type of reduction and should unite. This again emphasizes the importance and necessity of having this one particular view before fixation is attempted.

plished, with the limb held in neutral lateral position, rotated internally to the maximum, with traction maintained. We have not encountered paresis or paralysis of the sciatic nerve following heavy and sustained traction.

The neck must be shifted inside and under the head. In this position, with the limb in neutral lateral position, the fracture line at the neck looks upward, not medially. In the x-ray, the neck appears to have shifted medially in relation to the head. The line of weight thrust and muscle pull runs in a manner tending to impact the head and neck without shearing forces. This is the reason that neutral lateral position must be the position prior to fixation. The test of leverage, as provided by adduction, shows whether or not the neck fragment will stay under and inside the head fragment of its own accord.

If the hip is internally fixed in the position of abduction, even though the neck appears to be under and inside the head, this is not necessarily the position the fragments favor. After pinning, when adduction of the shaft occurs, leverage will be exerted at the fracture site. At first, this leverage will not be in line of weight thrust or fixation material. The leverage is first applied to the fixation material by the neck of the femur. The fixation material transfers this leverage to the head. The head then rotates to accommodate the shaft. Before the neck fragment can snug up inside and under the head, these adduction forces have acted. The inner portion of the neck fragment may slip by, and lateral to, the head fragment. The reduction, as described here, may therefore not be obtained.

When the limb is adducted to neutral, a small sandbag is placed between the knee and the table to prevent undue strain on the medial collateral ligaments of the knee. The limb is then draped in preparation for the insertion of the fixation material.

Occasionally, we are unable to reduce correctly a very oblique fracture or a fracture with comminution of the neck. In these cases, we favor gaining the desired position by an immediate osteotomy. This is more certain than an open reduction. We feel that open reduction is seldom the procedure of choice. It is unusual to fail to obtain reduction by closed methods, but if this should occur, an osteotomy seems to us to offer the patient the next-best chance for a good result.

In cases difficult to reduce, or in which the insertion of the nail we use might cause a reversal of our favorable position by pushing the medial portion of the head toward the midline of the body, we do the following. We not only center the neck and head with a $\frac{3}{16}$ inch Kirschner wire, but continue to drill the wire deep into the acetabulum. We feel that this fixes the head and holds the desired position until the head accepts the fixation material to proper depth (Figs. 18, 25).

The Fixation Material.—Any inert fixation gadget that holds the desired position should prove adequate. When reduction is inadequate, adduction of the affected limb, which is a normal physiological position of the human femur, plus the downward push of the trunk, tends to push

the neck outward and upward and thus to bypass the head. Since there is little or no resistance to this motion furnished by the neck, the effect of these shearing forces is transferred to the fixation material. The force of bone working against metal is an impossible physiological setup. Bone



Fig. 25—A, Same case as Figure 23. A, B and C Hip without nail, shown in A, is now eight years post-pinning. Nail was removed five years postoperatively. Hip showing nail is two and one-half years post-pinning. B The more recent fracture. Similar in type to its fellow, as shown in Figure 23, A, B and C. Note abnormally long "beak" on medial portion of neck fragment. C, Shows marked traction by Soutter apparatus, with inadequate reduction. Compare with Figure 23, D, E and F. D Shows adequate reduction.

shows area on upper and outer portion of head that suggests aseptic necrosis. Note lack of bone production about old fracture site. Compare with Figure 23, G, and with Figure 26.

melts away, and the metal loosens. The bone must hold the metal. The metal cannot hold the bone.

When the neck fragment is under and inside the head fragment and reduction is therefore adequate, adduction of the limb throws the inner side of the neck against the head fragment. This tends to rotate the

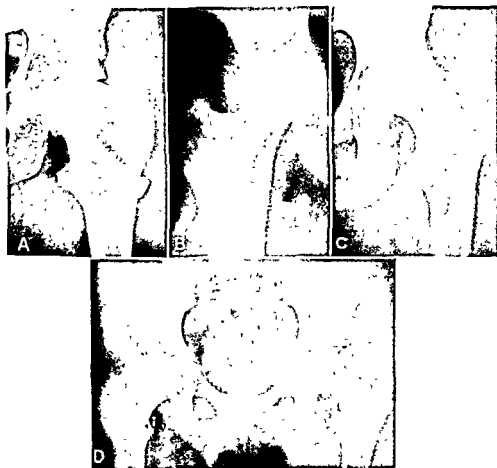
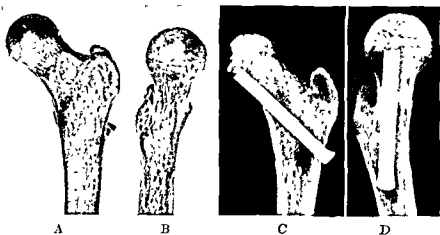
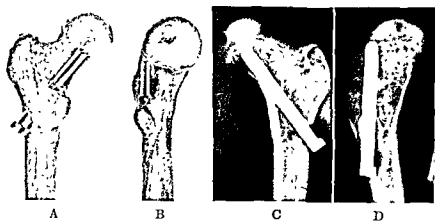


Fig. 26 —A, "Molten flowing" and delayed union of head and neck at fracture site, three years post-pinning B, Aseptic necrosis moderately advanced, five years post-pinning Note that fracture site is well healed, with no evidence of bone proliferation about it. Aseptic necrosis occurs proximal to the fracture site and is most marked in the upper, outer quadrant of the head. C, Complete aseptic necrosis of femoral head, four years after fracture of the posterior lip of the acetabulum and traumatic dislocation of the hip. D, Aseptic necrosis in adolescent hip, following closed reduction and fixation of slipped upper femoral epiphysis. Aseptic necrosis, as shown in B and C, closely resembles aseptic necrosis as seen in adolescence following slipping capital femoral epiphysis D. A apparently shows a different process, which is related to delayed union and nonunion at the fracture site. A illustrates a far more common result in hip pinning than do B and C. If the type as illustrated in A could be markedly decreased, or eliminated, a larger percentage of good hips would be obtained. We feel that the result illustrated by A can be greatly influenced by adequate reduction and immediate bony union. The results shown in B, C and D are dependent, more or less, on the amount of blood supply afforded the femoral head. Aseptic necrosis is a normal physiological process, resulting from loss of blood supply and replacement of bone. "Molten flowing," or delayed union, therefore, is influenced far more by correct reduction and fixation than is aseptic necrosis. Compare with Figures 23, 24 and 25.

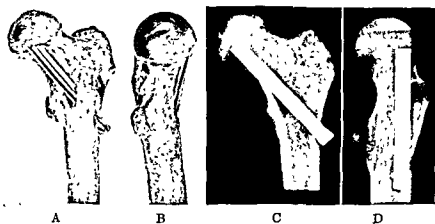
head fragment with the shaft, and support of bone to bone is achieved, with little or no force transferred to the fixation material if it is correctly placed in line of the femoral column (line of weight thrust). Further-



Series I

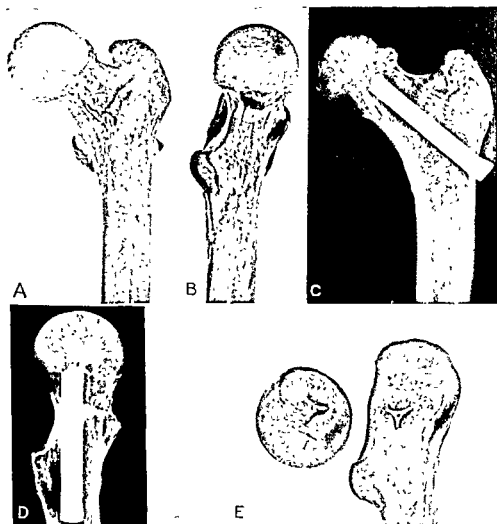


Series II



Series III

Fig. 27. (For legend see continuation of figure on facing page.)



Series IV

Fig. 27 (Courtesy of Dr. Morton Leonard) —Dr. Leonard has shown by his studies the importance of careful centering of the fixation material in both dimensions.

Series I. Accurate and true anteroposterior and lateral photographs and x-rays of a femoral neck and head. Note true length and angle of neck, and that lesser trochanter barely shows. Compare with x-ray views taken in identical positions.

Series II and III. Photographs and identical x-ray views of imperfect nailing, such as is exhibited also in Series I.

Series IV. Nail well centered. Note that photograph is not a true anteroposterior view. The lesser trochanter shows. The neck appears foreshortened, with the

center each hip with a guide wire that is proved well centered by excellent x-rays in the anteroposterior and lateral positions.

more, since the head, whether it is in valgus or not, sits on the neck in more or less of a crater, the downward thrust of the trunk tends to impact the fragments, rather than to angulate and distract them. The only force that can break up these favorable factors is one that disengages the

fragments. The most potent force in accomplishing this would be external rotation of the neck on the head. This normally is not too great a force if the head moves easily, but when the limb is artificially frogged, it may become a potent force.

The cannulated Smith-Petersen nail can be accurately centered in both planes and put parallel to the line of weight thrust. Thus, it offers no resistance to impaction. The nail is rugged, requires but one wire to center it accurately, is safe when carefully used, and, as far as we can determine, does not greatly complicate the blood supply to the head.

A Plea for Standardization of X-Ray Views at Time of Reduction and a Study of These Before Insertion of the Fixation Material.—It is essential that all x-ray views be taken under standard conditions. Only in this way can cases be studied, standards of excellence developed, and prognosis given with some degree of certainty. In the case of the hip, one need only take an anteroposterior view in the positions of external rotation, neutral rotation, and internal rotation to satisfy himself that some standardization of hip views is essential in the case of fracture of the neck of the femur (Fig. 17).

An anteroposterior view of the hip taken with the limb in complete internal rotation shows no lesser trochanter, the complete neck length, the separation of the fragments, and no overlapping. In our experience, this view, and only this view, is of value in judging a satisfactory reduction (Figs. 18, 24, 27).

After repeated study described earlier¹, we feel that the value of an anteroposterior view in complete internal rotation, in case of a fractured femoral neck, is of extreme value. Depending on the findings in this view alone, one can decide whether to continue reduction or proceed with fixation. If fixation is decided upon, of course lateral views are essential. A hip should not be internally fixed until good anteroposterior and lateral views prove reduction (Figs. 18, 19, 24).

In cases of impacted fractures, a true abduction fracture can only be distinguished from an impacted adduction fracture by an anteroposterior view of the hip taken with the limb in complete internal rotation. The impacted adduction type of fracture should be reduced and internally fixed. The abduction type need only be internally fixed. This may not be necessary, but we feel it is safer to do so (Figs. 15, 20, 21).

No motion of the limb should be allowed from the time the reduction is accomplished until the skin is closed. Frogging the limb to achieve a lateral view has no place in good hip work. If the above method of reduction is used, there is no opportunity to frog the limb.

It is extremely important that the fixation material center the head and neck in both planes and that plenty of cortex surround the nail in both views and on all sides (Fig. 27).

As mentioned before, all measurements and settings for the roentgenograms should be taken by the technician and x-rays of diagnostic quality produced, showing the complete head and neck, before the actual operation is undertaken.

By x-ray, a satisfactory fixation is one in which the fixation material enters the shaft of the femur at or below the level of the lesser trochanter, runs through the low midportion of the neck parallel to the femoral column, and centers the head in both planes (Figs. 17, 19).

SUMMARY

1. The fate of the femoral head in relation to aseptic necrosis is probably determined at the time of neck fracture. Aseptic necrosis of the degree that causes absorption and collapse of the head is a comparatively infrequent complication in our series. Femoral heads that have been extensively deprived of their blood supply at time of injury, but which have united promptly with the neck, soon show disintegration and the complete extent of bone death. When no attempt at union with the neck has been made, but extensive damage to the blood supply has occurred, the proximal fragment often preserves its contour until weight-bearing is initiated.

At present it appears that little can be done to save a femoral head extensively deprived of its blood supply. It would seem that the deprivation of blood supply initiates the normal physiological process of death of bone and ultimate attempts at repair by replacement with new bone. We believe that this fact in itself has no major effect one way or the other upon the immediate bony union of the head and neck.

2. Nonunion resulting in separation of the head and neck has been an infrequent cause of failure in our series.

3. Delayed union or "molten flowing" has been the most common cause of failure in our series and in any series of hips we have had the opportunity to review. Delayed union, if untreated, remains in some cases as fibrous union, and in other cases bony union is eventually achieved.

The x-ray appearance of aseptic necrosis differs considerably from that of delayed union. The former is due to actual loss of blood supply. The latter is due to failure of immediate bony union.

In this paper we are attempting to aid in the differentiation between aseptic necrosis, a rare complication, and delayed union, a common complication.

Since aseptic necrosis to a degree that interferes in any way with hip function has been observed by us only once in our series of sixty-five hips, we consider it an infrequent complication as regards the *immediate future* of the femoral head.

If delayed union and nonunion can be decreased to the point where they become a negligible factor, the good results from hip pinning should be greatly increased. True aseptic necrosis following immediate bony union of the head and neck should then become the main cause of disability. We believe that at present this is not the case.

4. It has been stated that a normal hip always shows the lesser

trochanter in the anteroposterior roentgenogram. One may correct this faulty impression by placing any normal individual supine on the x-ray table and manually internally rotating both knees to the extremes. A film taken with the patient thus positioned will adequately demonstrate the absence of the lesser trochanters

Our series includes sixty-five consecutive fractured hips of the intracapsular type. No basilar fractures, fracture dislocations, or fractures due to tumor or radiation are included. There are sixty-four patients in the series, one patient suffered bilateral fracture.

Since 1945 all hips in this series have been operated upon at one institution. All hips have been carefully followed by clinical examination and serial roentgenograms.

Of these sixty-five hips chosen for surgery, the following data are offered. The longest follow-up in this series is now over eight years. The shortest follow-up is one year. This series includes the thirty-eight hips previously reported¹

	Cases	Per Cent
Aseptic necrosis...	1	1.53
Nonunion	2	3.06
Failure to reduce (osteotomy)	2	3.06
Delayed union	5	7.69
Deaths in hospital following pinning	1	1.53
Serious infections	0	0
Total failures	11	16.78

Since 1945 twenty hips have been pinned consecutively and have all been included in this series. There have been no nonunions and one delayed union. There have been two hips in which satisfactory reduction could not be gained, and rather than risk an inadequate reduction and delayed union, an immediate osteotomy was performed in each case.

In our series to date all cases showing proper reduction have promptly united. All failures, except the case we feel to be a true aseptic necrosis (Fig. 26, B) were inadequately reduced. Of the eleven cases classified as failures, improper reduction accounts for seven of these (the two nonunions and the five delayed unions). These seven cases account for 10.7 per cent of the entire series and 63.6 per cent of the total failures. Review of these seven cases convinces us that proper reduction might have been obtained in each case.

Many studies published on intracapsular hip fracture have classified failures into those with obvious nonunion, those with "so-called" aseptic necrosis, those with osteoarthritic changes, and so on. Other hips that show eventual bony union following what we term delayed union have even been classified as "fair" or in some instances as "good." The conclusion as to cause of failure in most instances refers

back to the interference with blood supply to the head fragment. No mention is made of the effect of delayed union.

True aseptic necrosis of the femoral head can and does follow many conditions such as traumatic dislocation, forcible closed reduction of some congenital hips, and other conditions in which there has been no separation of the head and neck. It also may follow an immediately and well united femoral neck fracture (Fig. 26, *B*).

The majority of cases reviewed in the literature that are classified as nonunion, aseptic necrosis, or osteoarthritis due to poor blood supply to the fragments, are, to our way of thinking, obvious cases of inadequate reduction resulting in nonunion, fibrous union, or delayed union.

It is to be noted that hips in this series are classified in two groups, with no relation to union or nonunion. All hips that have not united immediately and are not comparable by function and by x-ray to the normal hip of the patient are classed as failures, regardless of cause. This series contains no fractures in which an arthritic hip demonstrable by x-ray was present prior to fracture.

Fifty-three of these sixty-four patients were or are living normal lives and had or have returned to their former occupations and recreations.

Close study of this series is continuing. It is our hope to subsequently report this series in detail, giving special attention to the ultimate fate of the femoral head in hips having adequate reduction and immediate union of the neck fracture.

CONCLUSION

Certainly no contention is made that the above position is the whole answer to immediate union of femoral neck fracture. We do, however, make the following contentions.

1. This is one method that at least attempts to give definite standards to be obtained before fixation is attempted.

2. Merely using the standard of obtaining valgus at the time of reduction and using fixation material through the neck and head without first proving by x-ray that the neck fragment is under and inside the head fragment, often results in insufficient reduction and will lead to many more nonunions and delayed unions than the reduction advocated here.

3. The position described has, in our study, offered the best possible chance for immediate union of the fracture site.

4. In our series to date, all failures of immediate bony union have occurred in hips that have been pinned in the under-reduced position.

In our hands, osteotomy is now reserved for those cases in which a satisfactory reduction cannot be obtained, or in which, after fixation, failure of union is shown to be imminent or to have occurred.

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TREATMENT OF CONGENITAL DISLOCATION OF THE HIP

W. J. SCHNUTE, M.D.*

IN 1946, Dr. E. L. Compere and I described a method of treatment of congenital dislocation of the hip. At intervals we plan to review our series of patients with congenital dislocations of the hip and report our observations and any changes in the treatment that may become necessary.

Early diagnosis and early treatment of a congenitally dislocated hip certainly has a direct relationship to the end result. The children in this series have all been under 4 years of age; but, unfortunately, only one child has been younger than 1 year at the beginning of treatment.

The basic plan of treatment of these children has been the gentle manipulative reduction of the dislocated hip with the patient under general anesthesia. Gentleness in this manipulation cannot be over-emphasized. Forceful manipulation can only cause irreparable damage to the hip joint. The danger of additional injury to the shaft of the femur and to the epiphyseal cartilages of the femur and pelvis is always present. Under light anesthesia sufficient relaxation is obtained with gentle traction to permit reduction of the simple congenital dislocation of the hip.

Traction on the extremity is continued for five to ten minutes. It is important not to hurry this phase of the reduction. The hip is then flexed above 90 degrees, adducted across the pelvis, and abducted into the frog-leg position of 90 degrees or more abduction, 90 degrees external rotation and 90 degrees flexion of the knee. In most cases the reduction of the hip can be felt by the surgeon and an audible snap heard. This reduction can also be checked by a simple clinical test. If the hip is reduced and held in the frog-leg position, it will not be possible to extend the knee completely; if the attempted reduction has failed, the knee will completely extend with ease. A double, long leg plaster spica (Fig. 28) is applied and kept on for three or four months. Postreduction x-rays are necessary without exception.

At the end of three or four months the cast is changed, and a double hip spica cast is applied to hold the hips in wide abduction and internal rotation. This cast is worn for six to eight weeks and is then removed, following which bilateral long leg casts with a wide spreader bar (Fig. 29, 30) to maintain abduction and internal rotation are applied and continued for six weeks. At this time active hip motion is begun.

Rigid shank shoes fitted with a spreader bar of a length permitting maximum abduction and internal rotation of the hips, similar in con-

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Fig. 28.—Frog-leg cast. The patient is maintaining wide abduction and external rotation of the hips



Fig. 29 —Long leg casts with spreader bar, maintaining wide abduction of the hips which in this stage are held in internal rotation. Motion of the hips is begun



Fig 30.—Spreader bar attached to high top shoes, maintaining wide abduction and internal rotation of the hips but permitting greater freedom of movement of the hips and knees, and also permitting periods of activity without support.

struction to the Denis Browne splints, are to be made ready to replace the abduction casts.

The abduction boot splints are worn for six to eight weeks day and night and removed only for bathing. The interval of freedom from the splints is slowly increased over the next six months—at the end of which time the splints are worn only at night, and they are continued at night for one or two years or as long as necessary to develop a deep, adequate acetabulum.

The aim of the prolonged support of the hips in wide abduction and internal rotation is to develop and deepen the acetabulum by constant active pressure from the head. This has been accomplished in these patients.

A simple congenital dislocation was mentioned in a previous paragraph. This type of dislocation is in contrast to the dislocated hip associated with arthrogryposis multiplex congenita or multiple other deformities such as a congenital shortening of the femur, absent sacrum, or multiple deformities of the lumbar spine with neurological changes in the lower extremities. The reduction of these types of dislocations and the maintenance of the reduction is difficult and frequently disappointing.



Fig 31.—Original X-rays of the pelvis in internal rotation and external rotation, taken March 9, 1945 showing the bilateral dislocated hips and the shallow oblique acetabula



Fig 32.—X-rays, taken May 23, 1946, showing complete reduction of both hips with the appearance of deep, adequate acetabula.



Fig. 33.—Original x-rays, taken July 18, 1944, at age of $1\frac{1}{2}$ years, showing unilateral congenital dislocation of the hip and also a shallow oblique acetabulum.



Fig. 34.—X-rays, taken June 12, 1948, showing complete reduction of the hip. Acetabulum compares favorably in depth to the normal hip. Clinically, gait was normal, leg length was equal; and Trendelenburg was negative.

Occasionally reduction of the dislocation has not been possible at the first attempt; but after a week of relaxation in a cast holding a frog-leg position, a second attempt is usually successful. In one of the patients in this series, four gentle manipulations were carried out before reduction was obtained.

SURGICAL APPROACHES TO BONES AND JOINTS

JOHN J. FAHEY, M.D., F.A.C.S.*

This presentation will be limited to certain approaches that have been found useful in exposing the long bones and joints of the lower extremity. No attempt will be made to describe all the exposures, as this subject has been well presented in a few books devoted to approaches to bones and joints,^{1, 2} and in a chapter in one of the orthopedic texts.³

The proper exposure of a bone or joint aids in avoiding nerve injury and reducing hemorrhage, it minimizes muscle and soft tissue damage, healing is more prompt, and adhesions and scar formation are much less likely to occur. Screws, plates and other means used to accomplish fixation will require removal less frequently because of irritation, pressure and bursa formation, if muscles are properly separated at operation.

The application of a Martin bandage or a pneumatic tourniquet reduces blood loss and makes the operative field easier to visualize, thereby reducing the operative time and enhancing the chances of better technic. There is less requirement for repeated sponging, ligating vessels, and other factors which are unfavorable to healing. The extremity is elevated, and a Martin bandage is wrapped from the toes upward, each turn just overlapping the edge of the previous one. A towel which is triple folded is placed around the thigh, and the first three turns of the tourniquet are made loosely, before it is tightened. If the first few turns of the Martin bandage are made extremely tight, and at one place, there is a likelihood of the tourniquet twisting like a cord and damaging the muscles. This is particularly true where the thigh is heavy or the individual is obese. Bending the knee before the tourniquet is applied may prevent damage to the quadriceps, because when the tourniquet is applied with the knee straight, and the knee is flexed during the operation, there is a possibility of a partial rupture. A Steinman pin inserted anteroposteriorly through the soft tissues above the greater trochanter, and the application of a tourniquet above it, make possible a higher bloodless field on the thigh.

The length of time a tourniquet may safely be left in place depends upon the age of the patient, the circulatory status of the extremity, and the skill with which it has been applied. If these conditions are optimum, one hour and fifteen minutes is safe. Unusual prolongation of time may result in nerve and vascular damage. Where one might suspect that large vessels have been cut, before the wound is closed the tourniquet may be released and the vessels ligated, thus preventing a troublesome hematoma. In most instances, however, a pressure dressing after the wound is closed will control the hemorrhage.

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HIP JOINT EXPOSURES FOR DRAINAGE

In cases of pyogenic arthrosis which require drainage, an anterior incision may be used. This incision extends from the anterior superior spine downward for 4 or 5 inches. The sartorius is separated from the tensor muscle, and the capsule exposed and incised.

The hip may be drained through a lateral approach, such as is used for nailing intracapsular femoral neck fractures. The tendinous portion of the vastus lateralis is turned downward from the trochanter, the distal portion of the capsule is cut from the intertrochanteric line, and the hip joint is exposed.

The posterior approach, described by Ober,⁴ is usually more satisfactory because it takes advantage of gravity. This incision is made over the posterior portion of the femoral neck, in line with the posterior superior spine and the midportion of the greater trochanter. The fibers of the gluteus maximus are divided, and the obturator internus, superior and inferior gemelli muscles may be cut $\frac{1}{2}$ inch from their insertion, and the posterior hip capsule opened.

HIP EXPOSURES FOR RECONSTRUCTIONS, ARTHROPLASTIES AND FRACTURES

The supra-articular subperiosteal approach described by Smith-Petersen⁵ affords good exposure for the femoral head and neck, in many types of reconstructive operations about the hip. The same author, in his works on acetabuloplasty⁶ and arthroplasty,⁷ showed how the sartorius and iliacus could be reflected and the straight head of the rectus femoris cut, exposing the anterior acetabular wall. Preservation of the stump of the rectus tendon and the anterior inferior iliac spine frequently requires revision of the primary operation, because of calcification and spur formation in the stump. To obviate this complication, Smith-Petersen recently suggested that the direct head of the rectus be divided at its origin from the anterior inferior spine and reflected laterally, without being dissected from its sheath. The inferior half of the anterior inferior iliac spine is then sacrificed.⁸

Most intracapsular fractures of the neck of the femur can be manipulated and internal fixation performed through a lateral approach, with x-ray control. An incision is made on the posterolateral aspect of the femur (Fig. 35) from the middle of the greater trochanter downward, the length depending on the particular operation. The fascia lata is cut posterior to the tensor muscle. The vastus lateralis is then retracted anteriorly from the shiny attachment of the fascia lata to the bone, anterior to the gluteus maximus insertion, forming the upper portion of the lateral intermuscular septum. No retraction is required posteriorly. This incision exposes the upper end of the femur for osteotomy, blind hip nailing, biopsy, excision of tumors, or other operative procedures in this region, with little blood loss and minimal damage to the large vastus lateralis muscle.⁹

This incision permits excellent exposure in cases in which the blade plate is used for osteotomy or intertrochanteric fractures. The large plate is covered by relatively undamaged muscle, avoiding bursa formation and even subsequent drainage, which require removal of the plate. If the posterior tendinous fibers of the vastus lateralis is cut from its origin to the posterior portion of the trochanter (Fig. 36), in cases that require a long exposure, such as is necessary in using the blade plate, retraction anteriorly of the vastus lateralis muscle will be facilitated. When the incision extends this length, it is advisable to locate and clamp a few per-

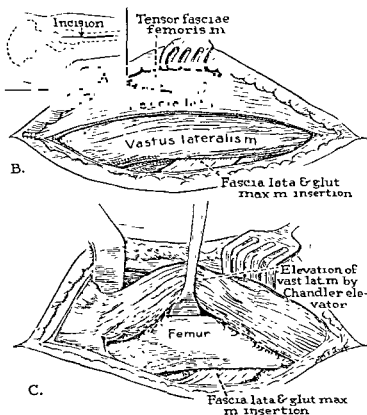


Fig 35—Drawing showing lateral approach to the upper femur for hip nailing, blade plate for osteotomy and trochanteric fractures, trochanteric transplants, and other operative procedures. The vastus lateralis is separated from the fascia lata attachment to the bone, anterior to the gluteus maximus insertion, and retracted forward.

forating vessels that pierce the lateral intermuscular septum, to prevent them from retracting.

HIP EXPOSURES REQUIRING VIEW OF FEMORAL NECK AND SUBTROCHANTERIC REGION

In certain operations about the hip, such as open reduction of fractures, osteotomy of the femoral neck, and fixation for slipped femoral epiphysis, it is necessary to expose not only the femoral neck and head, but the subtrochanteric region laterally (Fig. 37), in order to introduce a pin or nail up into the femoral neck and head. A similar exposure is desirable in per-

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forming the Brackett and Whitman reconstructions, where the trochanter is transplanted downward. A straight incision extends from the anterior superior spine to below the bulge of the trochanter. The skin is retracted medially, and the plane is developed between the tensor fascia femoris and sartorius. At the lower portion of the tensor muscle, the fascia is cut transversely. The straight head of the rectus is cut just below its origin from the anterior inferior iliac spine. The ascending and lateral branches of the lateral circumflex artery are tied as they pass beneath the rectus muscle. The psoas muscle is then identified and separated from the capsule of the hip, and retracted inward with a Chandler retractor, in the iliac fossa. The capsule of the hip is then opened longitudinally and cut transversely about $\frac{3}{4}$ inch from the acetabular rim. The vastus lateralis muscle is then retracted anteriorly from the lateral intermuscular septum. If the trochanter is transplanted downward, or the exposure is long on the upper shaft, the posterior tendinous fibers of the vastus lateralis are cut from the trochanter. In exposing fractures of the femoral neck, it is usually not necessary to cut the straight head of the rectus, but it gives better exposure for the reconstructive procedures.

POSTERIOR HIP APPROACHES

The Kocher incision¹⁰ for drainage has already been described. If the acetabular rim is to be repaired for fractures, or the sciatic nerve is explored, a satisfactory view can be accomplished by Osborne's incision.¹¹ This incision begins $1\frac{3}{4}$ inch below and lateral to the posterior superior iliac spine, extends to the superior portion of the trochanter, and runs downward along the posterior portion of the trochanter for a few inches. The fibers of the gluteus maximus muscle are separated, and the insertion of the muscle cut. The obturator internus and gemelli muscles are sectioned $\frac{1}{2}$ inch from their insertion and retracted laterally.

Exposure of the lesser trochanter is easily accomplished by a posterior approach. With the patient in a prone position, an incision is made on the posterior lateral aspect of the thigh, beginning 2 inches above the top of the greater trochanter. The plane between the vastus lateralis and fascia lata is established, and the gluteus maximus and quadratus femoris insertions are cut and reflected, and the lesser trochanter is exposed after the upper portion of the psoas is detached.

APPROACHES TO THE FEMORAL SHAFT

The type of exposure used will depend upon the type of pathologic involvement and its particular location in the femoral shaft. The antero-lateral incision¹² is made on a line between the anterior superior spine and the anterior portion of the lateral femoral condyle. The rectus femoris is separated from the vastus lateralis, and the fibers of the vastus intermedius muscle are incised. This incision is particularly suitable for lesions involving the anteromedial portion, as it permits good visualiza-

tion. It is unsuitable for securing good drainage, and is more likely to interfere with the return of knee function, because of the damage to the quadriceps. Henry² uses this incision for the upper and lower thirds, as well as the midportion. However, the descending branches of the external circumflex artery and the femoral nerve branches to the vastus lateralis and vastus intermedius are encountered in the upper third, and may be damaged. In the lower third of the femur, the vastus lateralis is closely adherent to the other muscles, forming the quadriceps, and one must be careful to avoid the quadriceps pouch.

The posterolateral exposure is frequently desirable. The patient is turned on the uninvolved side, or best with feet strapped to the foot of a

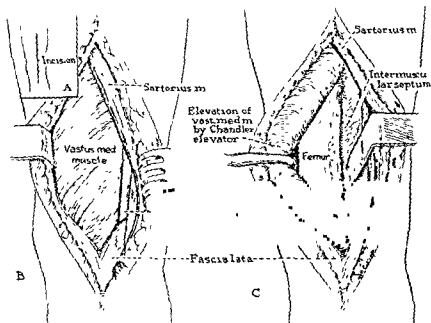


Fig. 38—Exposure of the lower medial aspect of the femur. The incision is made over the lower one-fourth of the posteromedial aspect of the femur, and the vastus medialis separated from the adductor magnus. If a more posterior exposure is desirable, the adductor is detached subperiosteally.

tilted Albee-Comper table. The incision extends from the posterior position of the trochanter to the lateral portion of the patella, and the vastus lateralis is separated from the lateral intermuscular septum. It is difficult to retract this muscle sufficiently for exposing the anterior and medial portions of the femur in extensive reconstructions, and lower down, perforating vessels pierce the lateral intermuscular septum, to reach the vastus lateralis muscle. However, in the upper third of the femur this

is not disturbed, and the muscle is not likely to be torn. This approach is especially suited to certain types of bone plating and in some cases of osteomyelitis, and has the advantage that the complete muscle flap covers the bone. It is particularly valuable in obtaining proper drainage.

If it is advisable to approach the posterior aspect of the shaft of the femur, the operation is best performed with the patient in a prone position, using the approach described by Bosworth.¹³ A posterior midline incision is made and may extend from the popliteal space to the gluteal fold. If the upper portion of the femur is to be exposed, the approach is lateral to the long head of the biceps. In the lower femoral approach, the entrance is medial to the long head of the biceps and sciatic nerve. In exposing the entire middle three-fifths of the femur, the lower attachment of the long head of the biceps is divided and retracted medially with the sciatic nerve. This exposure may be objectionable from the standpoint of necessitating the administration of anesthesia with the patient in a prone position, and the danger of injuring the sciatic nerve from pressure. Because of the possibility of involvement of the sciatic nerve, this approach is not advisable for drainage in cases of osteomyelitis. However, it may prove a valuable exposure in cases of scarring and drainage anteriorly, or for biopsy and resection of discrete benign bone lesions.

For lesions involving the medial and posterior portions of the lower one-third, the incision is made over the lower third, extending upward from the adductor tubercle (Fig. 38). The sartorius is retracted posteriorly, and the vastus medialis is separated from the adductor magnus tendon and retracted laterally. The adductor magnus tendon may be freed subperiosteally if it is necessary to expose the posterior portion of the femur in this region.

EXPOSURES OF THE KNEE JOINT

For draining pyogenic arthrosis of the knee, an incision is made on each side of the patella, extending from the quadriceps pouch to just below the joint level, a few inches long, and the synovial membrane is sutured to the skin.

A small straight incision may be all that is necessary to remove a loose body or perform a biopsy on the joint.

Frequently when the knee is explored, it is important to visualize the entire joint in order properly to remove a torn cartilage and inspect the opposite one, or to determine the source of the loose body or other pathologic condition. The median parapatellar incision is an excellent approach for exploration of the joint, removal of loose bodies, synovectomy, and repair of a fractured patella. The incision begins over the medial portion of the quadriceps tendon above the upper border of the patella, curves downward along the medial margin of the patella and patellar tendon, and ends just inferior to the tibial tubercle. The vastus medialis is cut from its attachment to the rectus tendon high enough so that the patella

can be dislocated over the condyle of the femur. The knee is flexed and both sides of the joint can be explored.

The posterior and medial compartment of the knee joint can be exposed by a longitudinal incision extending from just in back of the medial femoral epicondyle to the medial side of the tibia. The capsule is incised anteriorly to the sartorius muscles and the posterior part of the knee is explored.

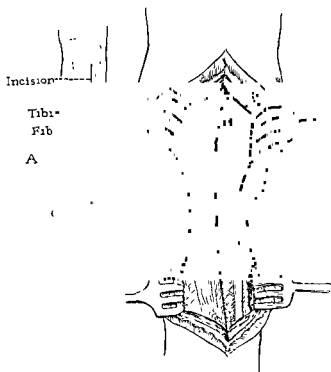


Fig 39 —Drawing showing posterior approach to the tibia. With the patient in the prone position, a posterolateral incision is made, and the gastrocnemius and soleus separated from the peroneal muscles, and retracted medially. The flexor hallucis longus is removed subperiosteally from the posterior surface of the fibula, and with the posterior tibial muscle and the long flexor of the toes, retracted medially. These muscles are not shown in the drawing.

An incision for exposing the posterior lateral compartment of the knee has been described by Henderson.¹⁴ It is made on the lateral side of the knee, anterior to the head of the fibula and biceps tendon. The biceps is retracted posteriorly and the joint opened.

APPROACHES TO THE TIBIA

Usually the tibia is approached through a straight longitudinal incision over the medial surface of the tibia, or by a curved incision with its convexity posterior. The curved incision has the advantage of having the scar over the soft tissue, rather than the bone. When the operation

can be performed on the lateral tibial surface, and it is desirable not to have the incision on the medial aspect, the incision can be made with its convexity laterally, but one should avoid having it pass transversely over the crest above and below.

In certain instances in which scarring or anterior drainage is associated with nonunion, a posterior exposure is advisable for performing a

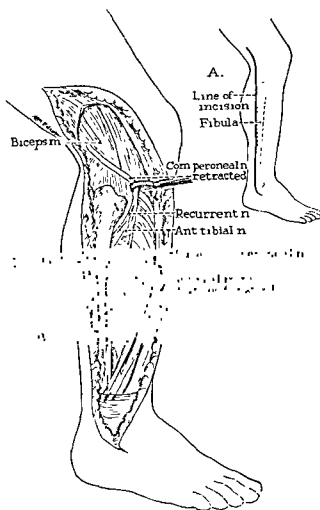


Fig. 40 —Drawing showing Henry's approach to the fibula. Through a postero-lateral incision, the common peroneal nerve is identified in the popliteal region, and on the lateral aspect of the fibular neck. The peroneus longus is removed from the fibula above the nerve, so that it can be retracted upward. The peroneal muscles are then separated from the gastrocnemius and soleus, and removed subperiosteally from the fibula, and retracted anteriorly.

bone graft. Such an approach has recently been described by Harmon.¹⁵ With the patient in a prone position (Fig. 39) an incision is made in the posterolateral aspect of the leg in its lower three-fourths. The gastrocnemius and soleus are retracted medially from the peroneal muscles. The flexor hallucis longus is then reflected subperiosteally from the posterior surface of the fibula, and retracted medially. The tibialis posterior is

removed from the interosseus membrane and the posterior surface of the tibia and, along with the long flexor of the toes, retracted medially, exposing the posterior surface of the tibia. It would not be advisable to use this exposure for the upper one-fourth of the tibia, as one is likely to damage the large vessels

APPROACHES TO THE FIBULA

The fibula is best exposed according to the incision described by Henry.² An incision is made from the posterior margin of the biceps tendon in the popliteal region, extending to the posterior tip of the

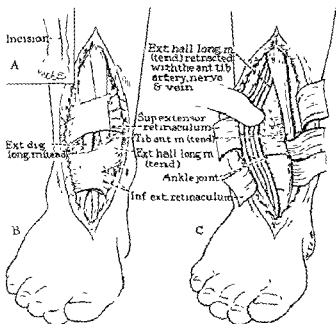


Fig 41 —Anteromedial exposure of the ankle joint for arthrodesis. The flexor hallucis longus tendon and tibial vessels and nerves are retracted laterally, and tibial tendon medially. This incision affords good exposure of the lower tibia for removing a bone graft. Extension of the incision exposes the astragaloscapoid joint.

fibula (Fig 40). The peroneus longus, above the common peroneal nerve is detached from the lateral surface of the head of the fibula, and then the nerve is retracted above the head. The peroneus longus and brevis are retracted anteriorly, and the soleus posteriorly, after these muscles are stripped from the bone. The lower portion of the fibula is subcutaneous.

APPROACHES TO THE ANKLE

Arthrodesis of the ankle and panastragular arthrodesis are two of the common operative procedures performed about the ankle. An antero-medial approach (Fig 41) affords an excellent exposure for these pro-

cedures. By retracting the long extensor of the big toe, the tibial vessels and nerve laterally, and the anterior tibial tendon medially, an excellent view of the ankle is obtained and a bone graft can easily be removed with a motor saw from the lower end of the tibia. The astragalus is easily accessible through this same view. The incision can be extended over the astragulo-scaphoid joint, if one contemplates doing a panastragular arthrodesis. In order to complete the panastragular arthrodesis, an additional incision is made from the tip of the external malleolus to the base of the fourth metatarsal. The calcaneocuboid joint is exposed by osteoperiosteal flaps, as advocated by Chandler.¹⁶ The soft tissue in the sinus tarsi is removed and the peroneal tendons are retracted posteriorly. The subastragular and calcaneocuboid joints are then fused, completing the panastragular arthrodesis.

SUMMARY

An appreciation of the anatomical structures and the proper exposure will aid in accomplishing the optimum end result in surgery of the extremities.

The type of exposure used to expose the long bones and joints will depend upon the pathology and the particular site of the bone or joint involvement. The presence of drainage or scar formation may necessitate the utilization of an exposure which avoids such areas.

The use of a tourniquet and the proper position will aid in accomplishing the operation easily and skillfully.

The retraction anteriorly of the entire vastus lateralis from the shiny attachment of the fascia lata anterior to the gluteus maximus insertion will simplify the surgical technic in performing fixation for femoral neck fractures, in the use of the blade plate for osteotomy and intertrochanteric fractures, and in other procedures in this region. There is less likelihood of subsequent bursa formation and other complicating factors which would require the removal of the fixing material.

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BONE GRAFTS

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By definition, a bone graft, like other grafts, is a transplantation of living bone from one location to another, with the anticipation that this transplanted bone will grow and regenerate in its new location.

It was not always true that living bone was used for the bone graft. My earliest experience was seeing an intramedullary ivory peg used. This certainly was a dead substance, and follow-up x-rays showed the ivory peg still in place many years afterwards, practically unchanged. There was no regeneration or bone stimulation as a result of the transplantation. Similarly, the beef bone graft, a dead substance, seldom if ever became a part of this living bone structure. The boiled graft, or *os purum* as described by Orell, falls into the same category of dead material and so cannot properly fit into our definition of living bone being used as a transplant. *Os novum*, also described by Orell, is boiled bone or *os purum* placed under the periosteum and allowed to become vascularized, and then this new bone is used as the transplant. I have never seen this type of bone used, although it is described in all textbooks.

More recently bone banks have been established. In this process living bone is removed from a donor site, then quickly frozen, and the bone stored for a variable period, usually not longer than six weeks. At the time it is used it is removed from the freezing chamber and transplanted directly to the recipient site. Is this still living bone, as insisted by some, or is it already dead bone? The answer to this is not yet completely available, but direct transplantation of living bone, or the use of "bone bank" bone, has today completely replaced the use of ivory pegs, beef bone, boiled bone, and the like. I cannot pass without making a comment about cow horn, used as a graft or peg. This material, introduced by Fowler, was supposed to be supple enough to be shaped or molded, which is true; it was also supposed to stimulate osteogenesis. We have used cow horn many times, and while it is a fair material for fixation, we have not been convinced that it has any value in stimulating osteogenesis and so have discarded it.

CLASSIFICATION OF BONE GRAFTS

Bone grafts may be divided into types according to their origin. The *autogenous* bone graft is one in which the bone is removed from the same individual and directly transplanted in another location. This is by far the most common type of bone graft today. The *homogenous* bone graft, from the same species, has been used more frequently in recent years and

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especially since the advent of "bone banks." Many times when addi-

cient bone, homogenous grafts are used. Our increasing violent traffic accidents and our recent war experience where large bone defects have resulted, have required more and more bone and have increased use of homogenous grafts. Bone bank bone may be autogenous, but usually it is homogenous, and those who are using bone banks freely are finding more and more uses for this bone. Many times we wish we had just a little more bone to pack around a fracture site—with more quite readily available in the bank it is rapidly used.

The *heterogenous* bone grafts, from other species, as the ivory peg, beef bone, cow horn, as mentioned above, have given away to the autogenous or homogenous grafts.

Another classification of bone grafts may be made according to the type of bone itself. The hard, firm, cortical bone is probably the most frequently used and the broad, flat surface of the tibia offers an excellent supply base. Grafts removed here may easily be cut to size, shape and thickness required since the tibia is readily accessible, being almost completely subcutaneous. From the surface of the tibia may also be cut the thin osteoperiosteal grafts that were so frequently used a few years ago and are still used by many today. These thin shaving-like grafts had periosteum still attached to a very thin layer of cortical bone and this combination of periosteum and cortical bone was supposed to have better power of osteogenesis.

The fibula is frequently used as a bone graft. This is chiefly a cortical bone, but the cortex is not as thick or hard as that of the tibia. The ribs are also used. Here again the material is chiefly cortical but the cortex is so thin that it is almost half way between cortical and cancellous bone, particularly when one considers the open ends of the rib grafts as being a good source of endosteal bone.

Cancellous bone is a more recent type, at least, for more general use. The chief source of cancellous bone is the posterior third of the ilium where large amounts of this type of bone may be removed.

WHAT IS THE FATE OF BONE GRAFTS?

If, according to our original definition, a bone graft is a transplantation of living bone, does this transplanted bone really live and survive or does it die? The work of Phemister has been outstanding in answering this question, and the more recent work of Abbott and his co-workers has added more definite information.

From early observations on boiled bone, beef bone and the like it was thought that all grafts died. The graft was considered a foreign body which owing to its stability could be used for fixation of a fracture. By being bony in substance it was thought to be a source of calcium salts

for ready deposition at a fracture site. I have never been able to rationalize this latter idea. If the bone grafts were dead how could the calcium salts get out of the graft to the fracture site? Also if calcium salts were the only answer to healing of a fracture why not inject some calcium salts directly into the fracture site and not bother with a bone graft? Furthermore, what about the general circulation through those parts—would not the excess calcium salts locally be picked up by the blood stream and be carried off as calcium ion? Phemister has shown that the grafts really die as soon as they are removed from the donor sites, but when placed into their new position, if the available blood supply is adequate, the bone graft will be invaded by new blood vessels. Along with these blood vessels new osteoblasts are formed and the graft itself is gradually invaded and replaced by new and living bone, or a creeping substitution of dead bone by new living bone. The process continues at least theoretically until all the dead bone has been replaced by living bone. There are many examples, however, that show that not all of the graft is thus replaced by living bone and a portion of the graft may remain for years as a segment of dead bone.

The more recent work of Abbott has shown this delay in revascularization of large cortical grafts. The under, or endosteal, surface of the cortical bone is usually replaced by living bone very early as is also the ends of the graft where they are in more direct contact with the circulation. The hard cortex is the last to be revascularized and the thicker the cortex or the larger it is, the longer time will it take for this process. In contrast, the value of the cancellous bone as a source of grafting material is apparent. The small pieces or even fairly large pieces of cancellous bone are chiefly endosteal in character and thus easily revascularized and osteogenesis is very rapid. Experimentally Abbott has shown that even after one to two days blood vessels and osteoblasts have invaded the cancellous bone so that the bone graft really does not die but immediately grows as living bone. Steindler has stated that the ideal graft must have both endosteal bone and periosteum. Abbott showed in his recent work that, at least experimentally, it did not seem to matter much whether periosteum was present or not; thus the value of the osteoperiosteal graft as a bone production graft seems to have been somewhat overemphasized.

FUNCTION OF BONE GRAFTS

In general bone grafts have two functions. The first is *fixation* either at a fracture site or across a joint line. The second function is the *stimulation of osteogenesis*. As discussed before, the best type of bone graft for osteogenesis is the cancellous bone, while for fixation the cortical is probably better. Thus the type of graft to be used will depend to a great extent on which function is the more important. More recently a combination of cortical and cancellous grafts have been used, the cortical bone for fixation and then packing around the fracture site with cancellous bone

chips. Specifically grafts are used in the repair of ununited fractures; to repair traumatic bone injuries and defects; to supply congenitally absent bone, as in the tibia or radius, to replace bone destroyed by infection, as in osteomyelitis; to replace bone removed for a cyst or tumor, to immobilize and stimulate osteogenesis as in a tuberculous joint; and to stabilize a relaxed and flail joint, as in poliomyelitis. With all of these possible functions, it is readily seen that no one type of graft has universal application but rather that the graft should conform, as much as possible, with the type of bone being grafted. In other words, shaft fractures do better with cortical bone while fractures near the end of the bone where there is proportionately more cancellous bone will do better with cancellous bone. However, if cancellous bone is used in the shaft area, the response of this bone is very great, and it seems to have the power to regenerate, not only to form more cancellous bone, but also to differentiate into forming good cortical bone, with a relatively normal medullary canal, as well as subcortical bone.

Formerly it was believed that the marrow, as from the tibia, had good osteogenetic properties and so, when a tibial cortical graft was removed, much of the marrow substance was removed as well and packed around the grafted area. More recent investigations have shown that this marrow substance has very little osteogenetic properties and should not be removed with the cortical graft. It will do more good remaining in the donor site, assuming its normal marrow function.

GRAFT TECHNIQS

In the technical application of grafts no details will be attempted in this brief article. There are so many technics each with its special indications that only the types will be described. Perhaps the earliest type of bone graft was the *intramedullary graft* used in the treatment of nonunion of fractures. In this procedure the bone ends are exposed, all callus or fibrous intervening substance is removed, the bone ends freshened by cutting away all sclerotic bone and then the medullary cavity curetted out of both fragments. The bone graft, and almost always cortical grafts are used, is cut and shaped as a peg and the bone peg inserted into the medullary cavity with the freshened bone ends brought carefully together. This type of graft frequently succeeds but, by virtue of the resected bone ends, it usually results in shortening of the bone being repaired. Mechanically it is unsound, because all of the stress and strain factors of motion are centered at the fracture line and the intramedullary graft frequently breaks at that point. If such a graft is used, it should be

have
days
or weeks the graft has been displaced completely away from the fracture site so it has lost its original function of immobilization. To obviate this some have advocated transfixion of the graft by two or more screws. To take the strain off the graft at the fracture site it would seem a more

logical procedure to add to the fracture site a long enough metallic bone plate; the screws that fix the plate would also transfix the graft. There may be some indications for an intramedullary graft but the disadvantages of the graft—shortening, poor mechanics, possibility of slipping, and the like—more than outweigh any advantages.

The *cortical inlay graft* is quite popular. Watson-Jones and others say this is the most common type of graft. I do not wish to differ too much with such eminent authors, but from my own experience, watching others and reading the more recent literature it does not seem that this type is as common as it formerly was. The technic of a good inlay graft is exacting; since many of us are not willing to be so meticulous or cannot be, this type of graft may not be used so often. The inlay graft may be a free transplant from another bone or a sliding inlay graft from the same bone. The cutting of the graft must be carefully done so that it will fit exactly into its new location. A properly fitting inlay graft needs no extraneous pins or screws for fixation. These, however, are frequently used, and must be added for stability if the fit is not perfect, probably because the surgeon has not cut the graft exact.

The usual technic is similar to that used for intramedullary grafts in that the intervening callous and fibrous tissue is all cut away, the bone ends freshened and made to fit exactly before the graft and its bed are cut. Thus the disadvantage of shortening the bone is still present. In many cases where this type of graft is used on the tibia the shortening is so great that the fibula must be resected or osteotomized for a sufficient amount to allow the tibial ends to meet. This graft is mechanically better than the intramedullary graft but there is still considerable stress and strain at the fracture site. To decrease this stress and to have actually a larger surface area of bone at the fracture site, Gallie has used his diamond graft which is a technical modification of the inlay graft.

The *cortical onlay graft* seems to me to be the most popular at present. Using this type of graft in the case of a nonunion of a fracture, the fracture site is adequately exposed and the periosteum stripped back only a sufficient amount to allow the graft to be fitted properly. Formerly the intervening callus, fibrous tissue and sclerotic bone ends were resected as when using an intramedullary or inlay graft. More recently it has been advocated to leave the callus, fibrous tissue, etc. in place. These tissues at least help to stabilize the fracture and if and when union takes place between the bone and the graft on both sides of the fracture line, the intervening material is frequently transformed into good bone. Thus, further shortening has not occurred. The graft is applied to one surface of the fractured bone, the cortex of which has been denuded slightly, at least sufficient to have a flat surface to receive the graft. The endosteal surface of the graft is applied to the denuded surface of the recipient bone. Usually this type of graft is transfixed by two or more screws, and thus being kept in close contact with the underlying bone it acts as a mechanical fixation. As in the other types of grafts, however, the mechanics are poor and considerable stress and strain takes place at the fracture site

where grafts are frequently broken. To obviate this mechanical disadvantage many advocate the addition of a metallic bone plate placed at 90 degrees around the shaft of the bone. Thus transfixion in two planes is obtained and stress and strain are minimized.

Very recently Phemister has advocated the use of the cortical onlay graft without any transfixion except that supplied by closing the periosteum and muscles over the graft area. The technic in brief is as outlined above for cortical onlay grafts. He stresses the non-removal of the intervening callus and fibrous tissue. A bed is carefully prepared to receive the graft by leveling off the cortex and stripping the periosteum only in a minimal amount. The onlay graft is placed endosteal surface against the denuded bone cortex and then the periosteum and muscles carefully closed over the operative site. Without anchoring the graft securely to the underlying bone, the mild stresses and strains are not imparted to the graft and less possibility of the graft breaking. The results look excellent. Immobilization is accomplished by a plaster of Paris encasement, which has to be of adequate length.

In all of the above intramedullary, inlay or onlay grafts, many are now adding some additional cancellous bone at the fracture site. The rationale is that the cortical bone is primarily an internal fixation device with some osteogenic properties while the cancellous bone being mostly endosteal in character will cause more bone proliferation. There are many modifications or combinations of the above types of bone grafts. Gallie's diamond inlay has been mentioned. Høglund's intramedullary, the sliding inlay graft, the notched inlay, Boyd's double onlay, a combination inlay and onlay, inlay at one end and onlay at the other, are only a few. The various textbooks and recent journals describe these in detail. In the recent war, where large bone defects were common, many ingenious grafts were used with excellent results; one could say that the exact type or technic depends mainly on the problem at hand and the surgical technic of the operating surgeon.

General Principles.—There are a few general principles that must be mentioned. First, and perhaps foremost, is a *scrupulous aseptic technic*. Many still advocate a strict Lane technic for bone surgery. This is excellent, especially if carried out in detail by all members of the operating

prove our general aseptic technic. One of the best ways to have a bone graft fail is to have a postoperative infection.

A second consideration is *gentleness in handling of tissues*. Although bone is a hard, firm substance, it should be handled carefully. The muscles should be divided cleanly, and complete hemostasis obtained. The periosteum is especially important. Indiscriminate stripping of the periosteum is dangerous. As mentioned above, only strip the periosteum as far as is necessary to apply the graft and afterwards close as much of the periosteal tube as is possible. If transfixion screws are used, they should

be put in accurately and should be long enough to penetrate both cortex of the recipient bone as well as the graft itself. Also, when using a screw remember that the hole in the graft and proximal cortex should be larger than the one in the distal cortex so that the graft will be in intimate contact with the underlying bone. In using motor saw and drill the bone must not be burned—a slow moving saw or drill with plenty of normal salt solution applied to the saw blade or drill will minimize this factor.

Before a bone graft operation is performed there should be good covering over the fracture site. By good skin is meant healthy, not scarred skin. A frequent preliminary step in the bone grafting procedure is the application of a skin graft to the operative site, either a split-thickness skin graft, a full-thickness or even a pedicle flap graft. Many times we have seen that a nonunion of a fracture has healed after an adequate skin graft, showing that the improved circulation provided by a good skin covering has also been sufficient to allow increased vascularity at the fracture site and subsequent healing of the fracture. Thus again good skin covering of the fracture site cannot be stressed too much.

Immobilization of the grafted area is equally important. Many now advocate balanced traction rather than plaster of paris immobilization if a plate has been applied in addition to a cortical graft (or combination of cortical and cancellous graft). The fact that some motion can take place in the joints above and below the fracture site aids in general circulation and hence local circulation at the fracture site and indirectly to better healing of the fracture. Also with some joint motion allowed there is less residual stiffness in the adjacent joints.

Many others, however, insist on definite plaster immobilization after a bone graft and such immobilization must continue until the graft is well healed and is solid. Watson-Jones is quite specific about this and, as mentioned above, Phemister has insisted on definite immobilization following application of his onlay graft. If such plaster of paris immobilization is to be used it must be applied correctly. A poorly applied or inadequately applied plaster of paris encasement is worse than no encasement. Instead of relieving stress and strain it makes more strain and may itself be a causative factor in fracture or failure of the grafts.

For fractures of the tibia the minimal plaster of paris encasement should extend from the toes to the groin with the ankle in a neutral position and the knee at approximately 90 degrees of flexion. Then, and only then, can the torsional strains be eliminated. For fractures of the femur, the minimal encasement is from the toes to the groin but better yet a double hip spica at least to the knee. Fractures of the humerus are unique to hold even in a hip spica and must be checked and rechecked for position.

Fractures of the forearm and especially a fracture of both bones should have an encasement from the distal palmar crease to the axilla with the elbow at right angles. Frequently it is necessary to extend the plaster up over the shoulder to obtain sufficient immobilization. For fractures of

the humerus a shoulder spica is the minimum if plaster is used. Proper immobilization cannot be overemphasized. Many fractures that go on to a nonunion and consequently need a bone graft would have healed, had the immobilization been adequate or had been continued sufficiently long. Equally important then is the immobilization following a bone graft. Immobilization must be more than adequate and is continued until healing is complete.

INDICATIONS AND CONTRAINDICATIONS FOR BONE GRAFTS

The indications for bone grafts are numerous. In children they are seldom indicated for nonunion of fractures inasmuch as most children do not develop nonunion. Children do show the congenital nonunions particularly in the tibia. Also the congenital absence of a bone, such as

described later. In adults the indications are primarily for nonunion of fractures, replacement of large defects, (usually traumatic in origin and frequently infected) and fusion of joints.

Time itself is not a contraindication to the use of a bone graft. The fact that a nonunion has existed for several years is not sufficient reason that a bone graft should not be attempted. On the other hand, many times bone grafts are used in the treatment of fractures and are not really indicated. Better immobilization and sufficient time interval should be tried first—because a fracture of the humerus or tibia has not healed in twelve weeks is no indication for a bone graft, and yet we have seen bone grafts applied in such cases. The average healing time of a fracture at a certain location must be kept in mind and until that average time has expired we cannot conscientiously say there is a nonunion and hence the necessity for a bone graft.

The main contraindication to the use of a bone graft is infection. Formerly it was advocated to wait one to two years following an infection before attempting a bone graft, hoping the infection had become quiescent. Even then the trauma of the bone grafting procedure was sufficient to reactivate or flare-up the latent infection, a definite local infection developed and the bone graft sloughed out. Since the advent of sulfa drugs and penicillin the time interval has decreased, so that nowadays, waiting from six weeks to six months is considered adequate. In such cases adequate chemotherapy should be instituted before, during, and after the surgical procedure. Many advocate the giving of penicillin during and after a clean surgical procedure in the anticipation of preventing any accidental introduction of infection. This is probably a very good policy but it tends to make us a little less critical of our operating room technic and if used for that alone should be discouraged. For the safety of the patient it is excellent.

Many of the recent war wounds exhibited massive loss of bone sub-

stance, as well as loss of surrounding soft tissues. Primarily the infection was attacked first by adequate debridement and covering the infected areas with split-thickness skin grafts, preventing further infection and changing the wound from an open one to a closed one. When all signs of infection had quieted down the defects in the bone were filled in with bone grafts, penicillin being used freely. Perhaps nowhere before have such problems been present and only the ingenuity of the operating surgeon was the limitation as to the type of graft used. All types were used in almost all combinations and one has only to peruse the recent literature to read in detail the various technics. Our basic principles were adhered to, namely control of infection, adequate skin covering, a bone graft of sufficient size and consistency together with proper immobilization. More recently at some of the veterans' hospitals a further step is being taken in filling in of bone defects in infected wounds. The wounds are cleaned out, the defect filled with cancellous bone chips and a split-thickness graft applied all in one operative procedure. So far the results have been worth the experiment but probably more should be done before this is accepted as a universal procedure.

SPECIAL TYPES OF BONE GRAFTS

Arthrodeses.—To this point most of the references have been made to the uses of bone grafts for ununited fractures and associated conditions. It must not be forgotten that all arthrodesing procedures are themselves bone grafts, the fusion of one bone to an adjacent one by eliminating the intervening cartilage, and with the healing of the bones the complete elimination of motion at the particular joint occurs.

Arthrodeses are done primarily for two reasons, first for the elimination of infection, as in a tuberculous joint, and second for stability as in a poliomyelitis.

In the tuberculous joints with definite evidence of infection and destruction the remaining cartilage is removed and the adjacent underlying cancellous bone is exposed. In the knee the patella as a free cancellous bone may be removed from the ilium and packed around the fusion area. This whole area being mostly cancellous bone the addition of cancellous bone grafts is indicated, and fusion will probably take place sooner. At the hip joint the combined intra- and extra-articular arthrodesis seems best. In this procedure the remaining joint cartilage is removed so that the cancellous bone under the cartilage may be approximated and then, if the Chandler technic is used, the extra-articular portion of the fusion is also mainly cancellous bone. Additional cancellous bone may be removed from the ilium.

Spinal Fusion.—Spinal fusions are almost a special type of bone graft and yet the principles involved are the same. Originally the spinal fusion graft was done in the treatment of tuberculosis of the spine, to obtain immobilization of a segment of the spine, while not attacking the diseased

area directly as in the case of tuberculosis of the knee or hip. The Albee graft, taking a piece of cortical bone from the tibia and inserting it into the split spinous processes, depends upon cortical bone, at least on one side of the graft, growing to the cancellous bone of the spinous processes. In the Hibbs technic the spinous processes and laminae are denuded and then chips turned up and down, these chips being chiefly cancellous bone. In addition, the facets are curetted out and packed with cancellous bone. Thus, the Hibbs graft is a cancellous graft. Many variations of this graft have been described, the chief one being the addition of extra cancellous bone removed from ilium, and either held in place by the periosteum and muscles alone or by wires as in the Chandler technic, or locked into place as in the "H" graft as described by Bosworth. With the decrease in spinal tuberculosis most spinal fusions now are for immobilization only, to decrease the pain of an arthritis, to add stability to a mechanically poor back or a spondylolisthesis, or as a part of the operative procedure for removal of a herniated intervertebral disk.

Other joint fusions, like the triple arthrodesis of the ankle, result in a fusion between cancellous bones, and here one may expect a fusion in about three months. This short time interval is due chiefly to the rapidity of regeneration of the cancellous bone elements. In joint fusions, of the shoulder or elbow, which are also chiefly cancellous bone structures, if additional bone is needed it would be best again to use cancellous bone.

SUMMARY

In summary, there are many indications for bone grafts. The cortical bone grafts give better stability, when applied to a shaft fracture, or for a bone defect, but the ultimate revascularization and hence regeneration is slow and not always complete. Cancellous bone grafts are readily revascularized and show much greater power of osteogenesis. There is no one graft to be used in all cases, and the ultimate choice of grafting material and its application is very much up to the ingenuity of the operating surgeon. The basic principles of a scrupulous aseptic technic, not operating in the presence of infection, a good skin covering, and thorough and efficient immobilization must always be remembered.

SURGERY IN THE TREATMENT OF CHRONIC ARTHRITIS

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PERFECTIONISTS need not bother treating patients with chronic arthritis. The outcome of any effort directed towards the management of this disease is far short of the ideal. Improvements are relative. The best one can hope is some gain in useful movements, a measure of stability, or perhaps surcease from pain. But what may seem an insignificant benefit to a well person is often a major boon to one afflicted with a crippling disease. However gnarled and knotted, the patient must not be denied his chances to better his lot. Surgically a great deal can be done towards ameliorating the plight of an arthritic and we have several useful procedures at our disposal which can be directed to this end.

DIFFERENTIATION OF THE TYPES

A joint is a connective tissue organ. It connects and supports parts and permits movement passively. It does not move, but merely allows motion. Muscles make it move. The joint and the structures related to it are derived mainly from the mesoderm. As the primitive connective tissue develops into highly specialized gliding and supporting structures, articular cartilage and subchondral bone, it remains relatively undifferentiated, hence reactive and reproductive, beneath the synovial surface and within the cancellous spaces. Inflammation affects the young connective tissues of the joint as are found in the outer vascular stratum of the synovial membrane and in bone marrow. Wear and tear, or degeneration, involves the specialized, senescent elements as articular cartilage and subchondral bone. The *inflammatory* type of chronic, nontuberculous arthritis has been qualified variously as rheumatoid, atrophic, proliferative, infectious, synovial and ankylosing. In the young, it is called Still's disease and a particular variety which affects mainly the axial skeleton has been dubbed spondylitis rhizomelica or Marie-Strümpell type. Adjectives linked with the *degenerative* type of chronic arthritis are: osteo- or chondro-osseous, hypertrophic, traumatic, senile, spur-forming and its special variant affecting the vertebral column is given the name Von-Bechterew type of spondylitis. The term arthritis deformans is loosely applied to both types.

There are several differences between the two main subgroups of chronic nontuberculous arthritis:

1. Inflammatory or rheumatoid arthritis is a generalized systemic disease; it affects not only joints, but some other tissues arising from

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mesoderm: it may be accompanied by myocardial disease and subcutaneous nodules. Degenerative or osteo-arthritis is confined to joints only, usually a single one.

2. Rheumatoid arthritis starts commonly before the age of 40, it affects mostly pale, asthenic women though its special variant, spondylitis rhizomelica, is seen more often in men, it occurs mainly in light skinned people—people of Northern European extraction. Osteo-arthritis is a disease of the old, except following acute trauma it starts after 40 and affects the hardy and robust and may occur in any race.

3. Rheumatoid arthritis may be associated with foci of infection and manifests a predisposition to allergy, but is not necessarily caused by them. Osteo-arthritis is related to trauma, to obesity and mechanical misalignments (which are the causes of chronic trauma), to old age (which is protracted trauma), to arteriosclerosis, and to avascular necrosis of the articular ends of bones with death and collapse of the supportive osseous framework and corrugation of the articular cartilage.

4. During its florid phases, rheumatoid arthritis may be accompanied by fever, leukocytosis and increased sedimentation rate, and there is a great deal of pain and stiffness. Symptoms of pain and stiffness are mild or moderate in osteo-arthritis and exacerbations are due to added trauma or increments of weather.

5. Rheumatoid arthritis involves many joints, it tends to predilect joints rich in blood supply and in primitive connective tissues, that is, joints with extensive synovial membrane and bulbous articular ends as for example the metacarpophalangeal and proximal interphalangeal articulations. Osteo-arthritis affects fewer joints, usually one, it favors the traumatized and weight-bearing articulations as the hip and joints farthest from central circulation as the distal interphalangeal articulations.

6. X-ray films of the involved joint in rheumatoid arthritis may show almost uniform narrowing of the cartilage space, subluxations and sometimes complete effacement of joint with osseous trabeculae running from one bone to another, the articulating bones appear radiolucent, porotic, "atrophic." In osteo-arthritis, roentgenograms reveal narrowing of cartilage space at points of pressure and contact and condensation of bony substructure, there may be evidences of marginal spurs, osteo-cartilaginous loose bodies, widening and mushrooming of the articular ends and cystlike areas in them, but there is usually no sign of subluxation or ankylosis, the articular ends of bones appear dense, "hypertrophic."

7. The primary pathology in rheumatoid arthritis is inflammation of the primitive connective tissue elements of the joint as are found in the outer vascular stratum of the synovial membrane and in the subchondral marrow spaces with secondary erosion and displacement of the specialized elements as articular cartilage and osseous trabeculae. Inflammation proceeds through various phases of hyperemia, edema, cellular infiltration and tissue proliferation. Granulations sprouting from the sub-

synovial and subchondral spaces invade and erode the bony trabeculae and the articular cartilages; they unite as fibrous strands which may become converted into bone. In osteo-arthritis, the basic change is one of wear and tear, or degeneration of the specialized gliding and supporting elements of the joint. At points of trauma or weight-bearing the articular cartilage thins; it fissures and fibrillates. Since this central portion of the cartilage is avascular, it cannot repair or reproduce itself. The subchondral bone and the marginal cartilage which receive blood supply react by thickening and piling up of new bone or osteophytes, the opposed joint surfaces file each other, eburnate, they may interlock, but they do not ankylose.

There are instances of the so-called "mixed" arthritis. A joint may have been the seat of rheumatoid arthritis, but as a result of destruction of the articular surfaces, subluxation or other mechanical incongruities it becomes subject to self-inflicted trauma and merges into osteo-arthritis. Conversely, in old osteo-arthritis, the synovial membrane may become irritated by osteophytes and osteocartilaginous loose bodies and set up an inflammatory reaction.

There are two chronic joint disturbances which cannot be pigeonholed into either group. One of these is the so-called *pigmented villonodular synovitis*, and the other, *synovial chondromatosis* and *osteochondromatosis*. The former starts as proliferation within the outer or vascular stratum of the synovial membrane: areas of condensed and thickened connective tissue indent the surface layer of the synovial membrane and produce villi; the expanded synovial secreting surface pours out more fluid into the joint. The fluid is not readily absorbed: it distends the joint cavity, enlarges it. But in contrast to rheumatoid arthritis, granulations do not break through the surface layer of the synovial membrane and invade the articular surfaces and erode them. The villi may bruise one another, necrotize and cause intermittent bleeding into the joint cavity: they may even become matted together in a meshwork of friable fibrin; but there is no extensive surface-to-surface adhesion and scarring as in rheumatoid arthritis and the joint movement is not greatly impeded. Clinical differentiation between pigmented villonodular synovitis and villous phase of rheumatoid arthritis can easily be made by aspiration of the joint fluid and arthrograms. In pigmented villonodular synovitis, the joint fluid is pink or brown; it is serosanguineous; arthrograms after introduction of air will show smooth, unbroken, articular contour, a flocculent "bubbly" effect. The joint fluid in villous phase of rheumatoid arthritis is yellow and arthrograms may reveal shadows indicative of intra-articular adhesions or a rugged contour of the synovial pouch.

Synovial chondromatosis or osteochondromatosis is a matter of metaplasia of the primitive connective tissue elements within the synovial membrane. The latter arises from the same anlage as bone and cartilage and is capable of reproducing either one of them. In synovial chondromatosis or osteochondromatosis, cartilaginous or bony plaques are laid within the synovial membrane; they invaginate into the joint, hang li



Fig 42 — Manipulation, traction and exercises against tension. Manipulation, if gentle, is often beneficial and may help in mobilizing quiescent, stiff joints. It is especially useful for frozen shoulders when supplemented with hanging cast, or better still, skeletal traction. Immediately after manipulation of the shoulder, 5 to 15 pounds of weight is connected to the hook screw in the proximal ulna, as pain subsides the patient is encouraged to abduct and adduct his arm, flex it at the elbow, and extend and retract the forearm, setting of the deltoid. When an 8 to 10

bunches of grapes, break loose. As detached foreign bodies they in time traumatize the articular surfaces and cause them to break down, producing secondary degenerative changes.

SURGICAL AND RELATED MEASURES

Casts, Splints and Corrective Appliances.—Painful joints, whether due to rheumatoid or osteo-arthritis, are better put to rest by enclosing them in casts or splints and elevating the limb. In inflammatory or rheumatoid arthritis, it is especially important that the joints are splinted in the position of optimum function should ankylosis intervene. It is at times possible to obviate ankylosis by making the cast removable so as to permit periods of guarded exercises. Where there are flexion contractures, one may encase the limb in a plaster cast and correct the deformity by successive wedging or a turnbuckle device incorporated in the cast.

Traction, Exercises, Manipulation.—For flexion contractures, traction, preferably skeletal, is perhaps better than the wedge cast or turnbuckle splint since it permits muscle-setting and active exercises. Heavy traction is dangerous and one must be on guard against nerve stretching and paralysis. Occasionally traction and exercises against tension are supplemented by gentle passive manipulation of the joint, under anesthesia. The joints which are most often refractory to manipulation are the elbow and those of the finger. The shoulder responds best to repeated manipulation, aided by skeletal traction through the proximal ulna. In atrophic bones, especially around the knees, one always runs the risk of causing a manipulative fracture (Fig. 42).

"Débridement."—Early in the last century, Napoleon's surgeon, Baron Larrey, conceived the idea that pain and spasm in infected war wounds were caused by the bands that bridged their interior. The French verb *débriser* denotes detaching. The English word *bride* indicates that which is tied. To *débride* means to untie. Larrey introduced the term *débridement* into surgical literature signifying the act of releasing tight bands deep in wounds and not removing the debris. Used in its correct sense, *débridement* has a place in the treatment of chronic arthritis. Where intraarticular adhesions are tough and unyielding, a scalpel may be slipped into the joint and swept up and down severing all the tight bands that offer resistance. The operation is especially applicable in the knee where most of the adhesions are in the suprapatellar pouch. The knife is introduced under the kneecap and carried up in a plane parallel to the anterior surface of the femur or the posterior articular aspect of

the proximal ulna and collar and cuff sling to enable the patient to lean forward and exercise his shoulder against gravity and weight. In bed, the hook screw is

out to be beneficial since it corrected the flexion contracture of the knee. The opposite knee broke at the same level.

the patella Active exercises and quadriceps setting are begun soon afterwards.

Joint Aspiration and Lavage, Puncture of the Synovial Pouch and Drilling of the Articular Ends of Bones.—In old cases of rheumatoid arthritis when inflammation has burnt itself out and left a thick, fibrotic capsule the inner surface of the synovial membrane will keep on secreting fluid and fail to resorb. As a result, the synovial fluid accumulates within the joint and distends the articular capsule. Repeated aspirations followed by immobilization of the limb may help. When the aspirated fluid is thick and flocculent, two large needles are inserted into separate pouches of the joint cavity and fibrin and exudate are washed away with saline solution, under gravity. In recurrent effusions, one may advantageously rupture the synovial pouch into the surrounding muscles. In the knee for instance, a forceps is passed into the suprapatellar pouch and poked upwards under the quadriceps group of muscles in an effort to sidetrack the excessive synovial fluid. Based upon the assumption that granulations, . . . be the cause of int . . . has been advised . . . arthritic patients often obtain symptomatic relief following fractures of the articular ends of bones.

Arthrotomy for Removal of Osteocartilaginous Loose Bodies, for Erasion of Incongruities and Chylectomy.—Loose bodies in the joints may originate from the synovial membrane or from the articular ends of bones. When arising from the bones they are due to trauma or interruption of blood supply. In baseball pitchers and tennis players, in the course of forceful hyperextension of the elbow, a sizable piece of bone will often break off the tip of the olecranon process of the ulna. The detached fragment may interlock the joint or erode the articular surfaces. Its timely removal will improve motion and obviate frictional erosion of the articular surfaces. Often in degenerative or osteo-arthritis a large overgrown spur will impinge upon the opposed articular surfaces and impede joint movement. It too may beneficially be excised (Fig 43). However, in larger weight-bearing joints, as the hip, knee or ankle, excision of osteophytes and smoothing out of the rough, incongruous surfaces accomplishes little. It is not advised for people who have to eke out their living by standing on their feet.

Desensitization of the Joint.—Since Charcot's joints are often painless and at times serviceable in spite of the extensive disintegration of the articular surfaces, neurectomy of sensory filaments to the joint has been advised, especially in malum coxae senilis. One recalls the principle John Hilton formulated almost a century ago: "The same trunks of nerves whose branches supply the groups of muscles moving a joint furnish also a distribution of nerves to the skin over the insertions of the same muscles: and . . . the interior of the joint receives its nerves from the same source." Hilton further pointed out that the hip joint not only

receives sensory filaments from the femoral and obturator trunks, but also from the nerves of the sacral plexus, the superior and inferior gluteal and the sciatic. To isolate each of these sensory branches necessitates different incisions, several sittings and extensive exploration, especially when the articular branch of the sciatic nerve is sought for and severed. Is it not much simpler to cut the sensory nerves where they enter the joint? And are not these nerves severed in performing a mold arthroplasty of the hip or synovectomy elsewhere? A decade or two ago sympathectomy enjoyed a transient vogue in the treatment of rheumatoid

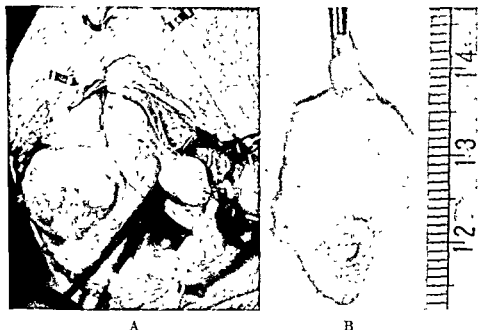


Fig. 43 —*Arthrotomy* The joint cavity is opened for a variety of reasons. For biopsy, for synovectomy, for arthrodesis, and for other intra-articular operations. The term arthrotomy is used here to denote the operation of extracting osteocartilaginous bodies, either floating loosely in the joint cavity or hanging into it by stalk.

A, Arthrotomy of the knee showing a mural, extrasynovial osteocartilaginous body hanging into the outer compartment of the knee. This was removed and the eroded articular surface of the patella was shaved (eration). B, Photograph of the specimen.

arthritis. It yielded no benefits beyond that accrued from postoperative sedation and rest.

Synovectomy.—In both villonodular synovitis and synovial chondromatosis or osteochondromatosis, synovectomy is regarded a standard surgical procedure. In inflammatory or rheumatoid type of chronic arthritis it is at times indicated. Rheumatoid arthritis will often resolve into villous synovitis with an extensive secreting synovial surface and persistent hydrops articularis. This so-called villous phase of rheumatoid arthritis is at times amenable to synovectomy. But before undertaking the surgery one must make certain that inflammation has completely



Fig 44.

Figs 44 to 47 —*Synovectomy* In rheumatoid arthritis where inflammation has abated, leaving an extensive inner secreting synovial surface (hydrops articularis and chronic villous synovitis) and a scarred outer layer with diminished absorptive power, synovectomy becomes at times expedient. Preoperatively, attempts should be made towards determining the extent of the inflammatory activity within the particular joint. When the joint is in a chronic state of hydrops, one must suppose that the inflammation is still active, or that the scarred synovial membrane fails to resorb what it pours out. In the last instance, the joint gains in capacity and arthrograms will not only reveal enlargement of the articular cavity, but also show shadows indicative of adhesions and scarring. Another method of ascertaining the extent of inflammatory activity is to introduce a few cubic centimeters of iodized oil into the articular cavity and take x-rays of the joint at periodic intervals. Where inflammation is still active the synovial membrane is hyperemic, the oil will soon pass out of the cavity and at times impregnate the lymphatic tracts and regional lymph nodes. Surgery will only fan smoldering fire. Synovectomy is safe where the oil remains unabsorbed for a month or more. On the whole, however, the results of synovectomy in rheumatoid arthritis are not very good since the hyaline articular cartilage is often irreparably damaged by the time the inflammation has burnt itself out. Synovectomy yields the best results in pigmented villonodular synovitis and synovial chondromatosis where the articular cartilage remains comparatively intact.

Fig 44 —*Presynovectomy studies as to the contour and the capacity and communication of the articular cavity*

A, Anteroposterior view arthrogram of the knee, of a woman with long-standing rheumatoid arthritis. Note the inordinate enlargement of the articular cavity the gastrocnemius semimembranosus bursa which ordinarily, is a small outpouching of the synovial membrane has descended as far down as the mid-calf. The contour of the joint cavity casts a jagged shadow indicative of scarring and the effect of irregular loculation is produced by bands of intra-articular adhesions. B, Anteroposterior view arthrogram of the knee of a young girl with bilateral pigmented villonodular synovitis. Her two brothers were similarly affected. Note the extension of the knee joint cavity up towards the mid thigh. The joint cavity when filled with air casts a multilocular shadow due to the infolding of the synovial plicae, the shadow cast by the contour of the cavity is smooth.

burnt itself out and is not likely to flare up. The duration of the hydrops, studies of temperature, blood counts and sedimentation rates may help one arrive at a decision. During the active hyperemic phases of inflammation the rate of absorption from the articular cavity is rapid; in late stages, due to scarring of the capsule, absorption is sluggish. A few cubic centimeters of iodized oil are introduced into the joint cavity and x-ray

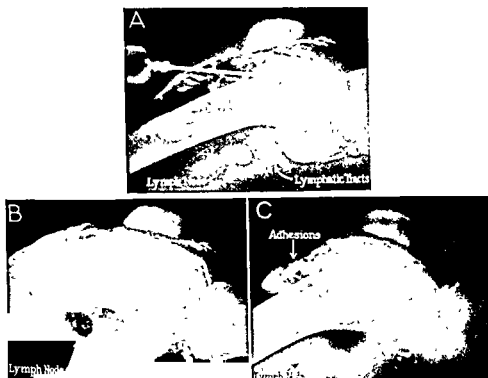


Fig. 45.—*Presynovectomy studies in the speed of absorption of iodized oil from the joint cavity.* The resorptive power of the synovial membrane is taken as an indirect index of hyperemia within its walls.

A, Arthrogram of the knee of a patient with fluminant rheumatoid arthritis. Iodized oil was introduced into the knee and the films were taken every twenty minutes. Already in the first plate opaque material was seen impregnating a large popliteal node and the lymphatics leading to and away from it. Increased vascularity enhances absorption from the joint cavity. (Reprinted from the author's article, "Chronic Arthritis", *Surg., Gynec. & Obst.*, 76:469-479, April, 1943). B, Arthrogram of a less active knee. The popliteal node became impregnated to the density shown after two weeks. C, Arthrogram of a quiescent knee. Three weeks after the introduction of iodized oil into the joint cavity the popliteal lymph node is only faintly impregnated. Note the jagged contour of the articular cavity which denotes scarring.

films are taken an hour later and then every two weeks. In burnt-out quiescent joints, lipiodol will remain in the articular cavity for weeks and months; when inflammation is active the oil is rapidly absorbed and may even impregnate the regional lymph nodes and tracts within the first hour of its introduction into the articular cavity. Any extensive surgery on the joint with rapid absorption, hence hyperemia, will only fan a

smoldering fire. Of all the joints, the knee and the elbow are most amenable to synovectomy. (Figs 44 to 47.)

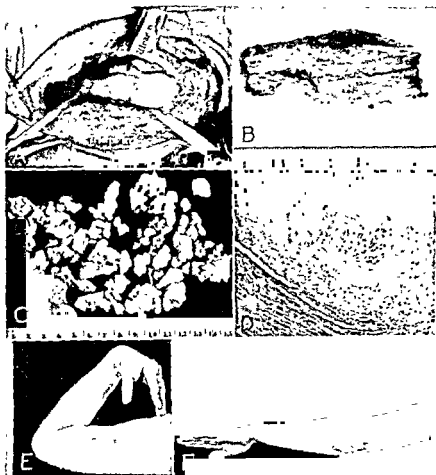


Fig 46 —*Synovectomy in chondromatosis of the elbow* The synovial membrane which arises from the same primitive connective tissue but remains relatively undifferentiated can produce both bone and cartilage by metaplasia. Synovial chondromatosis is usually diffuse, not only the detached loose bodies must be evacuated, but the membrane which produces them must be dissected out.

A, Photograph of the surgically exposed synovial capsule of the elbow of a woman whose only complaint was regional swelling and tingling along the distribution of the ulnar nerve. X-rays were negative. Note the distended synovial capsule on either side of the triceps tendon and adhesions extending to the ulnar nerve proximally. B, Segment of the chondrified synovial capsule to show its thickness. C, Multiform cartilaginous bodies with which the articular cavity was packed. D, Photomicrograph $\times 800$ through a section of the dissected synovial membrane showing nests of cartilage cells. E, and F, Functional results four months after synovectomy.

Capsulotomy.—In flexion contracture of the knee, posterior capsulotomy with stripping of the contracted capsule proximally from the

femur was a fashionable operation at one time. It was often supplemented by tenotomy of hamstring tendons. Nowadays posterior capsulotomy is resorted to only when the opposed articular surfaces remain intact, which is rare when inflammation has been severe enough to cause flexion contractures. The deformity is better corrected by supracondylar osteotomy.

Osteotomy.—In severe flexion contractures of the knee, a sizable wedge of bone is resected so as to avoid stretching and paralysis of the peroneal nerve during extension of the limb. The surgical fracture is allowed to heal in a functionally correct position, which in the knee is 5 to 10 degrees short of full extension. In the so-called *malum coxae senilis*, or degenerative arthritis of the hip, intertrochanteric osteotomy is sometimes resorted to with the idea of shifting weight-bearing points and putting a relatively unworn, mechanically sound, articular surface under the lines of stress and strain. The correction is best accomplished if osteotomy is performed between two guide pins which are used to lever the severed fragments of bone into the alignment desired. Recently osteotomy has been advised for the correction of bowed "bamboo" spine of spondylitis rhizomelica. Well planned and executed osteotomy of deformed fingers will improve their functional usefulness (Fig. 48).

Resection of Articular Extremities and Osteotomy.—In non-weight-bearing joints, resection of one articular end is to be preferred to the excision of osteophytes from it or effacement of its surface irregularities. In the lower extremity, resection of a non-weight-bearing bone, as the patella, is likewise justifiable and assures better functional result than trimming, rasping and filing of the bone.

Where the primary function is movement and stability is not an important factor, as in the temporomandibular joint, a considerable segment of one of the articular ends may be excised without any attempt at adaptive remodeling of the opposed surfaces (Fig. 49). In ankylosis or interlocking of the temporomandibular articulation, the condyle, the coronoid process and the adjacent portion of the proximal ramus of the mandible are resected; the space created is packed with oxycel gauze and skeletal traction is instituted through the chin. When the jaw has remained immobile for a protracted period of time, muscles of mastication become fibrotic; they contract, shorten; they must be put under stretch and made to function against tension so as to regain their length and contractility. Skeletal traction accomplishes this and it also prevents the chin from dropping back against the throat and choking the patient, postoperatively.

In osteo-arthritis of the acromioclavicular joint, an inch or more of the outer clavicle is resected (Fig. 50). In posttraumatic mushrooming of the proximal articular surface of the radius with inability to pronate or supinate the forearm, the head of the radius is resected. For the same reason in osteo-arthritis at the distal radio-ulnar articulation, or when the radius has shortened and ulna has advanced farther down towards the carpal bones, an inch or two of the distal ulna is resected.

In osteo-arthritis of the wrist following fracture of the carpal navicular



Fig 47—*Synovectomy in pigmented villonodular synovitis of both knees.* The synovial membrane presents a flattened connective tissue surface towards the joint cavity and an outer vascular stratum where most of the inflammatory processes take place. In rheumatoid arthritis, granulations break through the surface layer of the synovial membrane, invade the interior of the joint cavity, creep over and erode the hyaline articular cartilage and form adhesions. In pigmented villonodular synovitis, the outer stratum of the synovial membrane is thickened by

shown in arthrograms

A, Photograph of the knee at the time of arthrotomy of a young girl with bilateral pigmented villonodular synovitis. Both of her knees were markedly en-

and avascular necrosis of the proximal fragment, the dead piece of bone or entire carpal scaphoid or even all the proximal rows of carpal bones are sometimes removed. Resection of the carpal lunate is often performed in arthritis caused by necrosis of that bone and collapse of its articular walls. In arthritis of the metacarpophalangeal and interphalangeal joints, which often follows injuries, the globular head is resected (Fig. 51). Even though it may have been damaged to a greater degree, the base of the phalanx is left undisturbed since it gives insertion to the extensor muscles. The line of resection of the distal articular end of the metacarpus or of the phalanx must pass proximal to the point of reflexion of the synovial membrane over the head; if the line passes too far distally the blood supply of the head will be impaired and may result in ring sequestra.

In the foot, only rarely are metatarsal heads resected since these bones are weight-bearing. Exception is made in arthritis of the metatarsophalangeal joint following avascular necrosis and infraction of the metatarsal head, usually of the second. The nutrient vessel to the second metatarsal bone arises from the terminal perforating branch of the dorsalis pedis artery. It passes outward and plantarward and penetrates the bone nearer its base than its head. As the latter bears the only epiphysis of the metatarsal and constitutes its growing end, the direction of the nutrient vessel in the bone is proximal, towards the base. Whether or not this arrangement of the blood supply has anything to do with the infraction of the head is a matter of conjecture. The line of resection of the second metacarpal bone for infraction of the head should pass through where the bone receives adequate blood supply (Fig. 53). The arthritic base of the proximal phalanx is not touched since it would entail dissection of the volar metatarsal ligament which holds the toe in place. In the more common rheumatoid arthritis of the foot with hallux valgus, hammer toes and other deformities, the resection of portions of the proximal row of phalanges or of the entire set of these bones is regarded better surgery than excision of the weight-bearing metatarsal heads (Fig. 54). In hallux valgus type of deformity, the painful exostosis is chiseled off the medial aspect of the head of the first metatarsal and the proximal half of the first phalanx of the great toe is resected; if eroded or mushroomed, the two sesamoids beneath the metatarsal heads are also excised; the dissected aponeurosis of the abductor muscle is partly used to transfix the resected phalanx and its remainder is sutured to the severed adductor tendon.

larged, the synovial membrane is thickened and inflamed. The knee joint is shown in Fig. 44, B). In chronic effusion, the joint space is filled with fluid. This was this far from normal.

lla. C. Photomicrograph of synovial membrane showing inflammatory cell infiltration. D. Photograph showing the degree of extension of the disease after bilateral synovectomy.

The knees were operated at two-week intervals. E, Photograph showing the degree of extension.

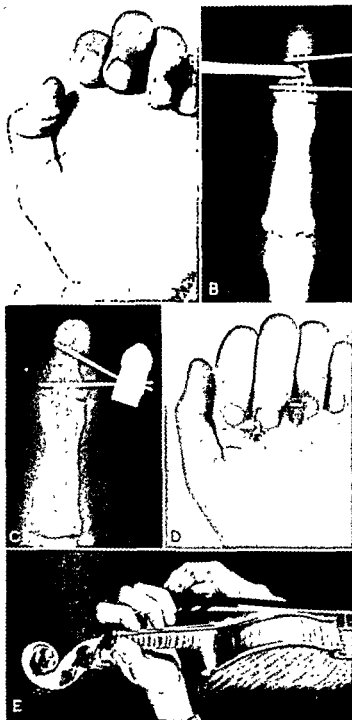


FIG. 48.—*Osteotomy* In flexion contractures of the knee, supracondylar osteotomy is a standard operation. Sometimes a considerable wedge or segment of bone is removed to obviate peroneal nerve paralysis on correction of the deformity. In the hip, subtrochanteric osteotomy is at times resorted to with the idea of

Arthroplasty.—Except in ankylosis of the temporomandibular articulation where one has no other recourse, it is questionable whether a painless, soundly fused joint should ever be mobilized. However, in some arthritics it becomes expedient to loosen a joint or two so as to enable the patient to feed himself or sit on a stool. When a joint has stiffened with the limb in a functionally useless position, the choice rests between corrective osteotomy and arthroplasty. Generally speaking, in the lower extremity where weight-bearing takes precedence over motion, corrective osteotomy is preferred; in the upper limb where movement is paramount, one may concede in favor of arthroplasty or resection of one of the articular ends.

Distinction ought to be made between the two methods of surgical mobilization of stiffened joints and the indications for each. In articulations, as the temporomandibular or acromio-clavicular, where stability is not a factor, adaptive remodeling of the articular ends is hardly warranted. All that is required is to resect enough bone, create a gap, and resort to such contrivances as would prevent this space from being bridged across by osseous trabeculae. In the elbow and especially the hip, where stability is a necessity, the resected articular ends must be reciprocally reamed and rounded and fitted together in a way that would prevent subluxation under use. Arthroplasty is thus more than mere resection of the articular ends. It denotes creation by art of a joint which will not only permit motion, but provide also a measure of stability under stress.

There are some general principles which must be heeded in performing arthroplasty in arthritics, especially in those afflicted with the inflammatory or rheumatoid variety. Before undertaking the mobilization of any joint, one must make certain that inflammation in that particular articulation, *not necessarily in others, has burnt itself out and that there*

shifting weight-bearing points and putting a relatively unworn articular surface under the lines of stress and strain. In the fingers, where osteo-arthritis often follows trauma and the digits deviate due to the obliquity of the damaged articular surfaces, osteotomy will not only correct the deformity but will also enhance the functional usefulness. (*The illustrations in this section are reprinted from the author's article, "Osteotomy of the Finger," Quart. Bull., Northwestern Univ. M. School, Chicago, 21(2):111, 1947*)

A, Photograph of the left hand of a violinist who suffered a handball injury about a year ago. X-ray revealed obliquity of the articular surface of the distal phalanx and degenerative arthritis. When he resumed playing the violin he became dismayed by his failure to hit the scale he intended to resound. Note the radial deviation of the distal phalanx of the long finger. B, X-ray film showing the transfixation of Kirschner wires and osteotome in place, within the substance of the distal phalanx. C, The distal fragment of the osteotomized phalanx has been twisted and levered into the desired position (ulnarward) and the two transfixation wires have been locked in a fixation nut on the ulnar side of the finger. D, Photograph of the same. E, Final photograph of the hand on the stringboard of the violin. The flexed distal phalanx of the long finger falls straight down on the string. It does not deviate sideways nor does it interfere with the play of the adjacent fingers.

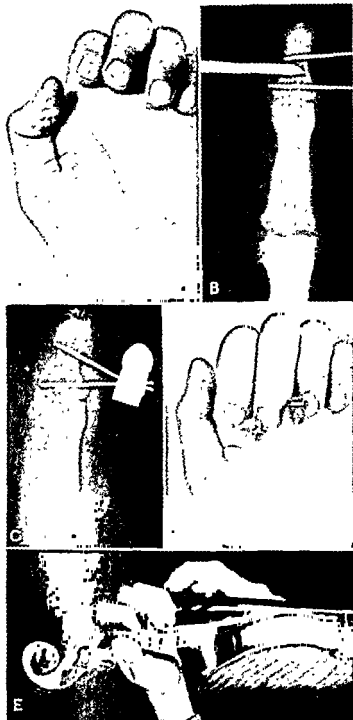


Fig. 48 —*Osteotomy* In flexion contractures of the knee, supracondylar osteotomy is a standard operation. Sometimes a considerable wedge or segment of bone is removed to obviate peroneal nerve paralysis on correction of the deformity. In the hip, subtrochanteric osteotomy is at times resorted to with the idea of

has been a considerable lapse of time, a year or more, since the last flare-up. Perhaps more important is the condition of the muscles around the joint. Arthroplasty is out of the question when the segments involved across the ankylosed joint must be levered by muscles which have been primarily involved in the inflammatory process or have shortened and atrophied beyond recovery. Muscles are the prime movers. Joints merely permit motion passively. In joints, as the shoulder, where too many muscles enter into intimate relation with the articular capsule and may have become primarily involved in inflammation, arthroplasty is doomed to fail. In the shoulder, the musculotendinous cuff constitutes the outer articular capsule and it inserts diffusely around the rim of the humeral head, not far from the center of joint action. In attempts at resecting and remodelling the proximal articular extremity of the humerus one cannot help but sever the insertion of the musculotendinous cuff. Being diffuse, the attachment of the cuff cannot be shifted down on the humerus. When the muscles related to the cuff fail to fix the head of the humerus against the glenoid, the deltoid loses its fulcrum and cannot lever the arm into abduction, the most useful motion of the shoulder joint.

In the upper limb the elbow is best suited for arthroplasty. The movements of this joint are based on relatively simple mechanics: hinge motion of the radius and ulna on the humerus and rotary movement of the radial head. Of the two main muscles which lever the forearm into flexion, only the brachialis anticus hugs the joint capsule and inserts too close to the axis of hinge motion. The brachialis anticus may have been involved in inflammation and its point of insertion into the coronoid process is usually sacrificed during resection and reshaping of the proximal articular end of the ulna. The other great flexor of the elbow, the biceps muscle, spans the joint at some distance from the articular capsule; it is seldom involved in primary inflammation; since the biceps inserts farther down into the radius than does the brachialis into the ulna, it is at a mechanical advantage to lever the forearm into flexion; its insertion need not and should not be sacrificed during arthroplasty of the elbow when the head of the radius is resected in order to liberate pronation

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sion against which the atrophied muscles can function and regain their contractility. In children excessive traction may cause subluxation of the cervical spine; as a precautionary measure the head and the torso are incorporated in a Minerva jacket. (The procedure described is amply illustrated and extended in an article by the author called "Temporomandibular Joint: A Method of Mobilization" *et al.*)

teeth have overlapped the lower and some of the incisors have dug their way deep into the opposite gum. *B*, Photograph a week after bilateral operation and institution of skeletal traction through the chin. Note the eroded upper gum into which the lower right canine was lodged.

and supination of the forearm. For stable hinge motion at the elbow, a semicircular notch is carved out of the proximal end of the ulna and the opposed surface of the humerus is reamed and rounded and made to fit loosely into it. The muscular attachments to the epicondyles may have to be stripped up, but they are not detached. It does not seem to matter greatly with what material the raw surfaces of the humerus and ulna are covered. Of late, oxycel gauze has come into favor. The space between the remodeled surfaces of bone is packed snugly with oxycel gauze



Fig 50 — Resection of the outer end of the clavicle for arthritis of the acromioclavicular joint due to old trauma. When there is associated calcification of muscular tendinous cuff of the shoulder, the overhanging acromial process and its articulation is likewise resected.

A, X-ray film before surgery. Note the erosion into the articular surface of the clavicle. B, X-ray after resection. C, Photograph showing the range of painless abduction three weeks after surgery.

and the wound is closed over it. A cylinder cast or a posterior mold is applied in order to procure rest and enhance healing of the soft tissues. Two weeks later the cast is removed and active exercises are begun against tension, preferably against skeletal traction through a screw in the proximal ulna.

In the lower extremity the hip lends itself best to arthroplasty (Figs. 55, 56). This joint is well supported by strong muscles and is deeply buried in them. It provides the surgeon with sufficient osseous material

out of which he can carve a ball and socket and create a reasonably stable articulation. The extensive raw surfaces of bone, thus produced, tend to reunite, but this is prevented by the interposition of a vitallium cup or mold. The greater trochanter, which gives insertion to the most important group of muscles around the hip, is transferred farther down on the femur. This shift is regarded as essential to a good arthroplasty of the hip since the tension thus created holds the newly carved and cupped head of the femur firmly against the acetabular roof. Moreover, the transplantation of the trochanter distally on the femur lengthens

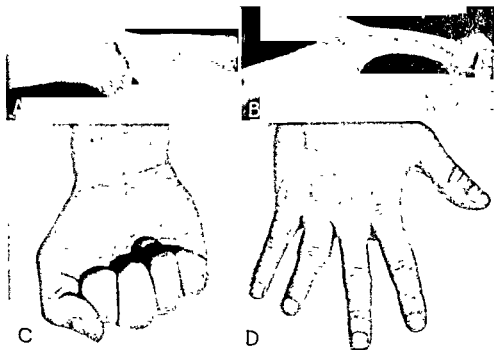


Fig. 51.—*Resection of the head of the first phalanx of the finger for arthritis of the proximal interphalangeal joint.*

A, Photograph showing resection of the head of the first phalanx of the long finger. The bone is dislocated through a longitudinal incision along the ulnar aspect of the finger and the head is resected at about the reflexion of the synovial membrane with a Gigli saw. B, X-ray following resection; note that the base of the second phalanx is left undisturbed. C, Flexion of the hand and finger two months later. D, Photograph showing the range of extension.

the lever—augments the mechanical efficiency of the glutei. The advantages of trochanteric shift are obviously offset if one has to strip the gluteus medius and minimus from their origin on the ilium in order to expose the hip joint. The hip joint is approached through an incision that avoids disconnecting any muscle from its origin. Occasionally in post-operative adductor spasm, the origins of the adductors from the pubis are stripped or the obturator nerve supplying these muscles is crushed or even severed. However, the adductors are regarded as less important muscles than the abductors and rotators.

Arthroplasty of the hip defeats its purpose when the glutei have to be stripped off their anchorage to the ilium during surgery or when these muscles are weak and functionally defunct as in long-standing ankylosis due to Marie-Strumpell variety of inflammatory arthritis. The best re-

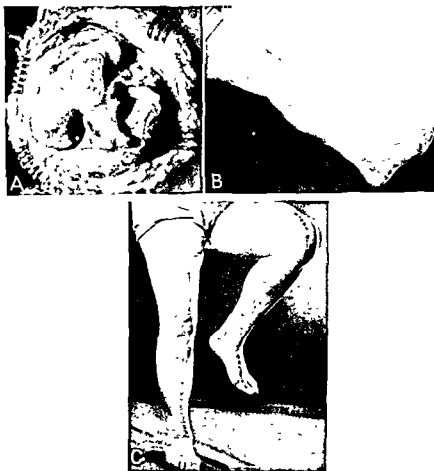


Fig 52. *Patellectomy* Excision of the patella is now a standard procedure for chondromalacia of the patella due to osteoarthritis of the knee joint.

graphs which were taken five months after the operation showing the knee in active extension and flexion respectively.

sults in arthroplasty of the hip are obtained in young adults with degenerative arthritis as follows Legg-Perthes' disease and old slipped femoral epiphysis with avascular necrosis of the head. In ancient unreduced subluxations and dislocations of the hip, mold arthroplasty is

difficult to carry out and is likely to fail; in these cases the head of the femur often points in one direction and the acetabulum gapes widely in

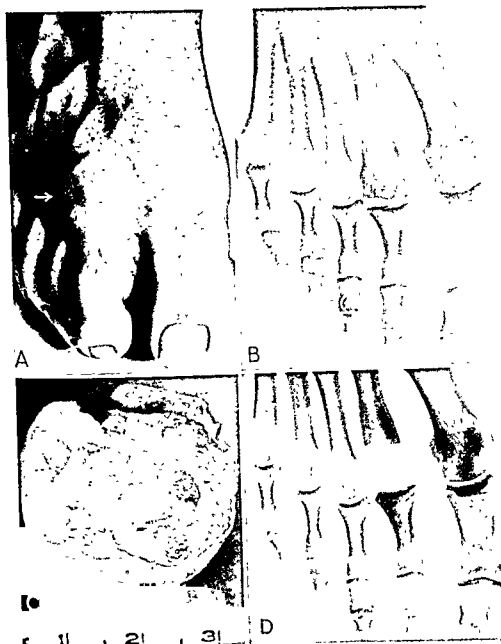


Fig 53 —Resection of the distal articular end of the second metatarsal for arthritis of the metatarsophalangeal joint resulting from avascular necrosis and infraction of the metatarsal head.

A, Photograph of the foot showing the swelling over the infractioned metatarsal head and the metatarsophalangeal joint. B, X-ray before surgery. C, Photograph of the resected articular end; the scales are in centimeters. D, X-ray after resection of the distal articular end of the second metatarsal.

another; the shallow acetabulum and its thin roof do not lend themselves to carving out a stable socket and are likely to extrude the cup placed in

them. In subluxations with anteversion of the neck and mushrooming of the head, one may trim out a strut and turn it into the socket and



Fig. 54 — Resection of the phalanges and osteotomy for correction of the deformity of the forefoot resulting from old burnt-out rheumatoid arthritis. Upper, Photograph of both feet before surgery. Lower, Photograph of both feet two months after operation. Through a curved dorsomedial incision, the bony overgrowth over the first phalanx was removed.

On the first metatarsal and sutured to the upper leaf was the adductor muscle, the lower leaf was tacked to the periosteum of the remaining half of the proximal phalanx. The proximal halves of all the first phalanges of the remaining toes were resected and the proximal interphalangeal joints were fused in the manner indicated for the finger in Figure 61.

hold it there by shifting the greater trochanter distally and posteriorly on the femur.

In old fractures of the femoral neck with avascular necrosis of the

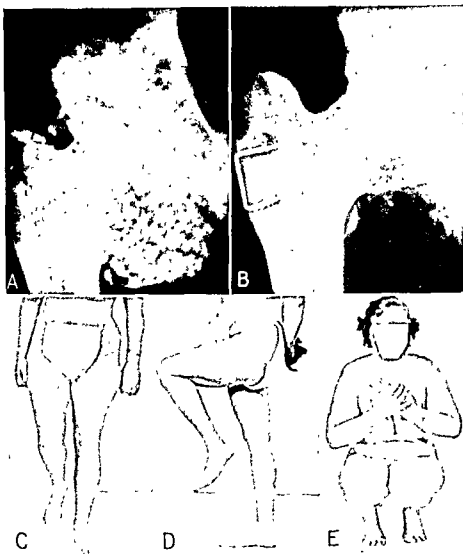


Fig. 55.

Figs 55 and 56 —*Arthroplasty.* In ankylosing or interlocking of the elbow, the hip, and rarely the knee, adaptive remodelling of the opposed articular surfaces becomes at times expedient in order to enable the patient to feed himself and sit on a stool. It is in these cases that the patient is often able to sit on a stool.

Fig. 55 —*Arthroplasty of the hip with reconstruction of a head out of the neck without interposition of a mold or cup, or even fascia.*

A, X-ray picture of the hip of a woman who had limped in childhood but did not have any complaint referable to her left hip until she became pregnant at the age of 22. The osteochondromatosis was interpreted as being due to aseptic necrosis and collapse of the articular end of femur resulting in degenerative arthritis. At operation, the femoral head was seen mushroomed and crumbled and there were over four hundred osteochondral bodies. These were removed. What was left of the femoral neck was reshaped and the greater trochanter was displaced downward on the shaft of the femur and tacked with a metal staple. (Reprinted from the author's article, "Pathological Physiology of Joints", Surg., Gynec. & Obst., 71:416-436, Fig. 23, Oct., 1940) B, X-ray of the hip fifteen years after surgery. C, D and E, Photographs showing the stability and the range of movements of the hip.

head and degenerative arthritis and in the so-called *malum coxae senilis*, the results of cup arthroplasty are variable. In both instances the deciding factors are the age of the individual, the muscles, and the bony substructure. In a weight-bearing joint like the hip, arthroplasty promises better results if the opposed articular ends of bone have hardened with

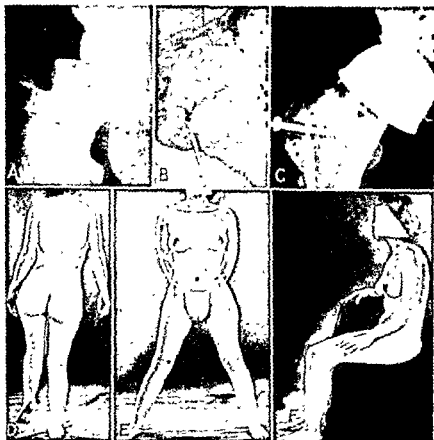


Fig 56—Bilateral cup arthroplasty of the hip for degenerative or osteo-arthritis due to old Legg-Perthes' disease. Both hips were similarly operated at two week interval

A, X-ray of the right hip before surgery B, The hip at arthrotomy. A probe is passed through a crevice over the head of the femur which tunnels under the articular surface and communicates with a crag posteriorly C, Anteroposterior view film of the right hip six months after surgery D, Trendelenburg test of the right hip. E, The extent of leg spread. Note that both hips had been operated F, Sitting

closely knit trabeculae since such bones stand up better under pressure, then again these bones are relatively poor in endosteum and postoperatively produce little bone that would block movements. In contrast, in rheumatoid arthritis, osseous trabeculae are sparse and endosteum is abundant; soft bone crumbles down under pressure, periosteum and endosteum throw off exuberant interlocking osteophytes and undo the

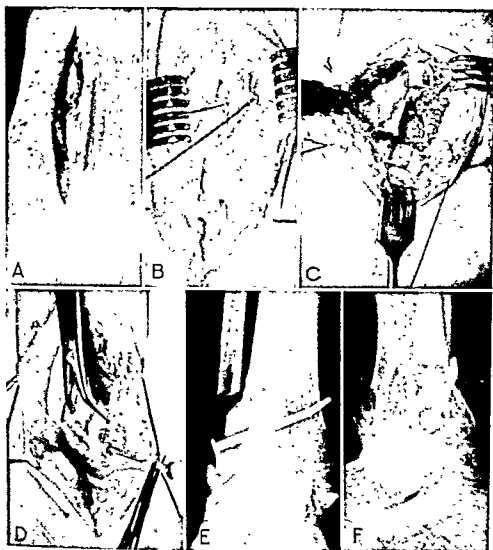


Fig. 57.

Figs. 57 to 61.—*Arthrodesis*. In the larger joints of the lower extremity, as the hips, knees, and especially the ankles, there is no better substitute to surgical fusion. The interphalangeal joints of the toes are occasionally fused for painful hammer toes. In the upper extremity, the wrist, the shoulder, and the hip are occasionally fused. In the upper extremity, the wrist, the shoulder, and the hip are occasionally fused. In the upper extremity, the wrist, the shoulder, and the hip are occasionally fused.

they are held together firmly until union takes place. Bone grafts enhance union; internal fixation eliminates the one major cause of pain and nonunion which is movement.

Fig. 57.—*Arthrodesis as applied to the ankle*. *A*, Photograph showing a longitudinal incision in front of the distal fibula and its malleolus. The incision is carried down to the skeletal plane and the skin flaps are retracted by sutures which are tied behind the leg and under the heel. Two periosteal retractors are passed around the distal fibula about 2 inches above the joint. *B*, The fibula is severed by a Gigli saw. The distal fibular fragment is dissected backward, exposing the joint. The fibular notch of the tibia and the fibular malleolus are denuded of cortical bone. *C*, A tunnel is developed on the fibular aspect of the tibia and the talus and the gouged-out spongy bone is packed between the talus and the tibia. *D*, The distal fibular fragment which had been denuded of cortical bone and articular cartilage but still remains attached laterally and in the back is turned into the talofibular tunnel and viewed from the medial view film of the ankle.



Fig 58 —Arthrodesis of the knee and fixation of the femur and tibia with two threaded bolts and long leg cylinder cast A, Frontal view film five months after surgery B, Lateral view of the same



work of arthroplasty Here one may resort to secondary chylectomy, packing the raw surfaces of bone with oxycel gauze, which is said to retard osteogenesis, or one may resort to a fusion operation.

Arthrodesis.—For painful, interlocking and contracted articulations there is no better surgical substitute to arthrodesis of the joint with the limb in functionally useful position. This is especially true of the joints of the lower limb where stability is paramount. In some purely weight-bearing joints, as the ankle, (Fig. 57), arthrodesis has no other alternative; in the knee (Fig. 58) it yields a more serviceable result than arthroplasty; in elderly patients with unilateral hip joint disease (Figs. 59, 60), it is again preferred to the mobilizing operation. Except in the wrist,



Fig 60.—Another method of arthrodesis of the hip using a bent plate and six screws for internal fixation. Three years prior to arthrodesis, a cup had been put elsewhere resulting in painful unstable hip. The glutei must have been stripped off their origin on ilium because the patient manifested positive Trendelenburg on standing and a lurch in walking. The cup was removed and the opposed surfaces of the femur and ilium were refreshed down to bleeding bone. The metal plate was bent to desired curve; it was countersunk into a groove across the greater trochanter and was transfixed to both ilium and the femur by six screws.

A, X-ray before arthrodesis B, X-ray six months after surgery showing solid osteosynthesis.

where there are no supporting muscles and numerous small bones enter into the articulation, arthrodesis is seldom performed as a remedial measure for chronic nontuberculous arthritis of the joints of the upper limbs. In the shoulder, fusion is occasionally advised for major musculotendinous tears leading to a painful, partly transfixed joint. Arthrodesis may at times be indicated for painful contracted fingers (Fig. 61).

Whittling and Amputation.—A deformed finger, which gets in the way of the others or a hammer toe which makes shoe wearing painful, may be disarticulated. In extremely deforming variety of rheumatoid or inflammatory arthritis, both lower extremities are sometimes twisted and

gnarled beyond any hope of correction. Nursing in these patients becomes an economic problem and the reward of many hours of arduous effort often may be fungating bedsores over the sacrum, malleoli and the heel. Will it not benefit the patient, as well as those who take care of him, if both useless legs were amputated just below the greater trochanter so that the wooden man could occasionally be allowed to sit up or transferred into a wheel chair?

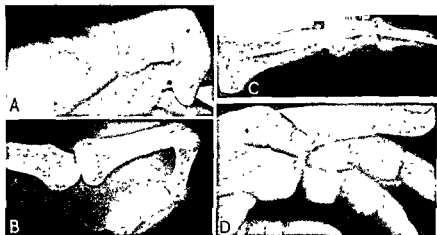


Fig. 61—*Arthrodesis of the finger* A, Photograph of the hand of a young woman, a hairdresser. Note the marked flexion contracture of the small finger. The scar along the ulnar aspect of the finger is the remnant of a previous attempt at lengthening the tendons by a graft, which resulted in failure. B, X-ray of the finger. C, The interphalangeal joints were fused by invaginating the denuded distal ends of the proximal bones into the base of the distal bones. An intermedullary Kirschner wire is threaded to hold the bones together. The wire, and with it, the finger are bent to suit the functional demands made upon this finger by the occupation of hairdressing. D, Photograph of the finger two months after surgery.

SUMMARY AND CORRELATION

To recapitulate, a joint is a connective tissue organ. It connects and supports parts and permits motion between them. It does not move. It allows motion. Its function in health is thus passively mechanical: it is structurally adapted to yield to motion and support. In disease, the relatively undifferentiated connective tissues or the yielding elements, as are found in the synovial membrane and in marrow spaces, set up an inflammatory reaction, the specialized structures—articular cartilage and subchondral bone—wear out, degenerate. Numerous adjectives have been coined to qualify the type of chronic arthritis characterized mainly by inflammation in contrast to the one whose salient feature is degeneration. The terms rheumatoid and osteo-arthritis are the least confusing and are chosen to denote the inflammatory and degenerative variety respectively. It is suggested that pigmented villonodular synovitis is akin to the villous phase of rheumatoid arthritis, yet different from it; synovial chondromatosis or osteochondromatosis has some of

the features of both main types of chronic arthritis, but is unlike either one of them. Both villonodular synovitis and synovial chondromatosis are amenable to the same surgical measures (synovectomy and removal of loose bodies) which have been found useful in the treatment of chronic nontuberculous arthritis.

Inflammatory or rheumatoid arthritis is regarded a systemic disease: any measure which will benefit the patient's general health will help to improve the joints involved. Surgery in this disease aims at putting the painful joints at rest (splintage); in overcoming and correcting contractures (traction, turnbuckle splints, wedging of cast, manipulation, débridement, tenotomy, capsulotomy, osteotomy and ostectomy); in eradicating residual inflammation (synovectomy); in mobilization of the already ankylosed joint (arthroplasty); in elimination of a painful articulation (arthrodesis); and in getting rid of gnarled useless limbs (amputation).

Degenerative or osteo-arthritis is a local disease. The treatment should aim at the elimination of the causes of trauma to the particular joint as overuse, obesity and mechanical misalignments. Surgery is indicated in the presence of painful or interlocking loose bodies (arthrotomy); when there are incongruities of opposed articular surfaces which might beneficially be eliminated (erosion, chylectomy, resection of non-weight-bearing articular ends); when there are reasonable chances of procuring a comparatively unworn bearing surface and improved mechanical alignment of weight-bearing segments (osteotomy); when the joint is interlocked and necessitates mobilization (arthroplasty), and when it is painful and needs to be eliminated (arthrodesis).

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ACUTE AND CHRONIC OSTEOMYELITIS

MARY S. SHERMAN, M.D.*

NOWHERE has the influence of the antibiotics been more spectacular than in the reduction of the incidence of osteomyelitis. The ear, throat and skin infections of children which were once so commonly followed by hematogenous infection of bones are now prevented or minimized, and even when such an infection becomes established, it is rarely followed by complications. Furthermore, these drugs have permitted the use of previously impossible technics in the handling of those bone infections which still result so that surgical treatment is now much less time consuming, less dangerous, and much more satisfactory.

It is customary to list three types of osteomyelitis: acute hematogenous infection; osteomyelitis by direct extension from adjacent infection; and infection of bone by direct contamination as in compound fractures. Actually it makes little practical difference by what route the infectious agent arrives at the bone except that the infections which are not blood borne tend to be less virulent and to remain better localized. Each case must be evaluated individually and the appropriate treatment chosen after all factors have been carefully weighed. It is of course true that compound injuries are apt to present a mixed bacteriology and also to include certain organisms, such as those of gas gangrene, which are rarely found otherwise. In 90 per cent of the hematogenous lesions the infection is due to hemolytic *Staphylococcus aureus*. Next most common are streptococcus and pneumococcus infections. The very small percentage of cases not included in these groups includes instances of osteomyelitis due to every known suppurative organism from typhoid and salmonella to brucella. In infants the relative incidence of streptococcal infection is higher. Needless to say, cultures are essential to the diagnosis and treatment of any case of osteomyelitis.

ACUTE OSTEOMYELITIS

Acute hematogenous osteomyelitis, although it may be seen at any age, is essentially a disease of childhood and adolescence. As stated above, it results often as a complication of a pre-existing infection such as a boil or an otitis media. Trauma is almost routinely mentioned as a predisposing factor, but its role is impossible to assess, and probably of minor importance.

Symptoms.—Although it is obvious that at some stage in the evolution of the hematogenous lesion there must be a true bacteremia, this is us-

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ually insufficient to cause symptoms. Most frequently the initial picture is of a child who is acutely though not dangerously ill. He has localized pain and tenderness and while these may be related to any bone of the body, they are most commonly situated over the metaphysis of one of the long bones of the extremities. There will be swelling, redness, and local heat, all of which are more pronounced if the disease is old enough so that a soft tissue abscess has formed. Motion of adjacent joints is usually limited by pain, but acute tenderness is localized to the area of bone involvement. The systemic manifestations include fever with its attendant dehydration, and an elevated white count. If bacteremia is significant, so that the blood culture is positive, all the above findings are present and in addition acute prostration. The patient is gravely ill with a high fever that may lead to delirium, coma, and death.

Pathology.—In this early stage of the disease, there are usually minimal or no bone changes demonstrable by x-ray. The bone is filled with pus which may even have broken through the cortex to produce a subperiosteal abscess, but these are soft tissue changes. A little later, when bone absorption has begun, a region of decreased density appears. At the same time, reparative processes are at work. The stripped-up periosteum begins to form bone (involucrum) between it and the cortex. When areas of bone have been killed, either by the cutting off of their blood supply or perhaps by bacterial toxins, they gradually separate from the living bone to become sequestra. These sequestra are absorbed exceedingly slowly and, as long as they are present, act like foreign bodies in keeping alive the infection. Eventually, if treatment is delayed, the pus either burrows through the periosteum, the involucrum, and the soft tissues until it breaks to the outside, or it spreads up and down within the bone and even to adjacent joints. In addition, all the time that the focus is active there is constant danger of further metastatic spread via the bloodstream. By this time the patient will have developed such non-specific effects of a severe febrile illness as dehydration, weight loss, and anemia.

Differential Diagnosis.—It is evident, even from this brief consideration of the evolution of acute osteomyelitis, that early treatment is desirable. This of course implies early diagnosis which is not difficult if the possibility is kept in mind. The disease most frequently confused with osteomyelitis is *rheumatic fever*. The child with rheumatic fever rarely is as acutely ill as the child with osteomyelitis, nor does he have as high a fever or white count. Furthermore, although he may have pain in one or more joints, he does not usually have such exquisitely localized tenderness nor feverish swelling. Sometimes an osteomyelitis is mistaken for a *sprain or fracture* because of the occurrence of trauma (something which is mentioned in the history of almost any childhood disease) but the systemic manifestations should preclude this error. Differentiation from abortive or mild paralytic *poliomyelitis* may occasionally be difficult in young children. However, acute osteomyelitis is usually a much more

severe disease. With care, bone tenderness can be distinguished from muscle tenderness and a spinal puncture can settle the question if necessary. Occasionally it may be necessary to distinguish between osteomyelitis near a joint and a *primary septic arthritis*. The distinction is readily made by aspiration of joint contents. The only other acute febrile disorder which is easily confused with acute osteomyelitis is the *idiopathic cortical hyperostosis* of infants which was described by Caffey in 1945. Although the general symptoms and findings of Caffey's disease may be very much like those of acute osteomyelitis, the roentgenographic picture is fortunately diagnostic.

Treatment.—Since one may see the patient first at any stage of an acute osteomyelitis, treatment cannot be standardized but must depend on a careful evaluation of the individual case. In general there are three lines of attack:

1. *General supportive measures* must not be neglected. These include adequate fluid replacement, transfusions of whole blood if anemia is present, analgesics and sedatives. Hot packs may be of benefit in relieving pain and in helping to localize the infection.

2. *Chemotherapy* is of the utmost importance and should probably be used for every patient. Of the sulfa drugs sulfadiazine is the most generally useful. However, it has more undesirable side effects than penicillin and since both drugs affect essentially the same organisms, penicillin is the agent of choice for most patients. It should be started as soon as the diagnosis is made. If cultures or smears should demonstrate an organism insensitive to penicillin, such as *Escherichia coli*, streptomycin can be substituted, but in view of the severe toxic effects of this drug on hearing and balance it is probably wise not to use it in the absence of specific indications. The use of penicillin in the early stages has lessened the urgency of surgical intervention, but has not replaced surgery. Failure to diagnose properly and failure to use antibiotics early enough and in sufficiently large doses still result in conditions which cannot be handled successfully by nonoperative treatment alone.

Whether or not the antibiotics will in themselves be sufficient therapy depends largely upon the stage of the disease when the patient is first seen. Very early in the acute phase, before there has been abscess formation and necrosis of bone, penicillin in adequate amounts (20,000 to 40,000 units intramuscularly every three hours or more if bacteremia is present) may cause the process to resolve entirely with no other treatment. When it does so, the usual sequence of events is apt to be profoundly altered. The clinical response is often dramatic, but the drugs must be continued for three to four weeks after the temperature has fallen to normal. The x-ray findings are also changed. There is far less subperiosteal new bone produced and unless the process is incompletely arrested there is not the usual marked sclerosis. There may be a small amount of bone killed, but this often reorganizes without evident sequestration. This is particularly true of infants and young children.

Although penicillin may sterilize the blood stream, and sometimes even the contents of a bone abscess, it does not cause pus to absorb. Therefore when delayed treatment has resulted in abscess formation it is probably wise not to rely on drugs alone. Furthermore a certain percentage of apparent penicillin cures will relapse later on and require further treatment, usually surgical.

3 The indications for *surgical drainage* in acute osteomyelitis have been and are still the subject of a good deal of disagreement. However, more harm has probably been done by failure to drain than has ever resulted from early surgical intervention properly done.

In this clinic it has been the practice to drain whenever there is definite indication of a localized process. This procedure has not been abandoned since the advent of chemotherapy, but it is no longer considered to be immediate emergency surgery. It is possible, with the use of penicillin, to delay a bit until the patient's general condition is as good as possible and then to perform surgery if the process is still not controlled.

This initial intervention should not be undertaken with any idea of eradicating the disease, but purely to provide drainage for confined pus. If one keeps in mind the evolution of the disease, it is at once obvious that simply incising a soft tissue abscess is not always sufficient. Even though the bone may appear to be normal, a small window removed from the cortex at the site of greatest tenderness will reveal pus within the bone. If this pus is not provided with a sufficient exit, it will make its own route which will probably be much less desirable. The defect created should be packed lightly and the limb immobilized. General therapy is of course continued.

Four to six days later when the first dressing is done, a certain number of these lesions will be found sufficiently clean to permit of secondary suture. When this is possible, it shortens greatly the healing time (Fig 62). If there is any doubt, however, the lesion should be repacked and allowed to granulate in.

The only deviation from this procedure is in the case of infants. As has been mentioned, they have a higher incidence of streptococcal infection, and the course of the disease is somewhat different. Since the bones of infants are less compact, the pus tends to break out more readily so there is less tendency to involve massive amounts of bone. For the same reason there is apt to be more periosteal stripping and earlier pointing of the abscess to the outside. For these infants there is less need for early operation. If the lesion is still confined within the bone, chemotherapy alone will often suffice. When operation is necessary, simple soft tissue drainage combined with chemotherapy will usually result in prompt healing. Once these lesions heal, and they do so much more rapidly than in older patients, they tend to stay healed and not to produce late exacerbations or metastases (Fig. 63).

In adults with acute osteomyelitis the picture is much the same except that the evolution is slower. For them and for those patients who have

an acute flare-up of a chronic osteomyelitis, treatment is essentially the same.

Complications.—Complications of acute pyogenic osteomyelitis cannot always be avoided.

1. Since the bone infection is usually primary in the metaphysis of

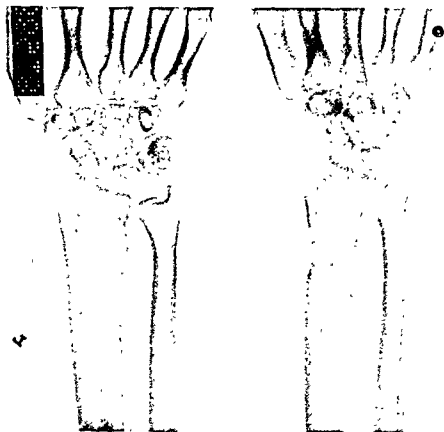


Fig 62.—A boy of 18 had had osteomyelitis of the right tibia four years before admission. This had healed after several operations and caused no further trouble. Three years later he had a painful swelling of the right wrist. With hot packs and sulfa therapy this subsided in ten days. One year later the trouble in the right wrist recurred and the first x-ray (*left*) was made. It shows thickening and sclerosis of the entire lower radius, evidence that there has been a low grade infection for a long time. In the center of the metaphysis is a radiolucent area which, at operation, was found to contain hemolytic *Staphylococcus aureus* pus. The second picture (*right*) shows the extent of the operative defect which was packed with petrolatum gauze. Five days later the pack was removed, the skin edges freshened, and the wound closed. Healing occurred without drainage. Intramuscular penicillin was given for three weeks.

long bones, *extension into adjacent joints* is not uncommon. This is particularly true in a location such as the upper femur where a large part of the bone is actually intracapsular. When pyogenic infection of a joint has been established, early drainage is imperative so that pus may be evacuated before the articular surfaces have been severely damaged. One cannot depend upon penicillin as this agent does not cross into joints

in anything like the necessary concentration. Persistence of pus within the joint can lead to death of the ossification center and pathologic dislocation

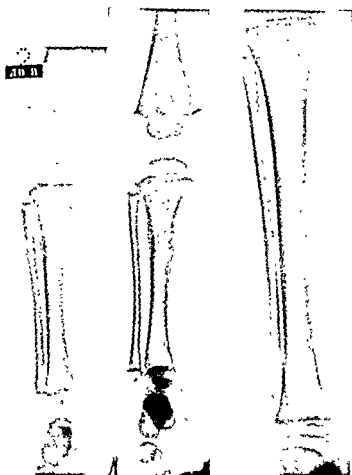


Fig. 63—An infant, aged 6 months, had had fever (102°F), pain, and tender swelling of the right leg for fifteen days. She had had an unknown (but small) amount of sulfa drug when the first roentgenogram was made (left). There is a spotty decrease in density in the metaphysis and a layer of periosteal new bone on both sides of the upper shaft. On this day an abscess was evacuated from the periosteum, but the bone was not affected. The abscess was evacuated by the removal of the molytic streptococci was evacuated. The x-ray at that time showed a more uniform appearance of the bone structure.

may appear in other bones or in soft tissues
 5. *Clinical bacteremia* may occur. Even this condition which used to carry such a high mortality, now frequently yields to the antibiotics.

4. *Pathological fracture* through bone weakened by disease can occur easily. When it does, the infection is apt to be aggravated and nonunion may supervene.

5. *Growth disturbances* not infrequently follow osteomyelitis in children. If there has been much damage to the epiphyseal line there may be complete arrest of growth. If the damage is less complete so that one portion of the plate closes and the rest continues to grow, deformity will result (Fig. 64). Both of these conditions must be kept in mind so that



Fig 64.—A 9 year old boy had had acute osteomyelitis of the lower right femur for four weeks. There had been no specific therapy because the illness had been diagnosed as rheumatic fever. After penicillin was begun a large abscess was evacuated and a window was made in the bone where more pus was found. The organism was hemolytic *Staphylococcus aureus*. The wound was packed open and penicillin continued both locally and intramuscularly. *A*, Roentgenogram made one month after onset of disease. *B*, One month later the roentgenogram shows that a 2 inch segment of bone has separated and appears as a dense sequestrum in a cavity in the metaphysis. *C*, Five months after surgery the roentgenogram shows organization of sequestrum and involucrum, and no sign of active disease. By this time there had been no drainage for eight weeks. *D*, Taken three years later, shows complete healing of the osteomyelitis. In spite of infection and fracture the epiphysis is still open, but growth has been more rapid on the medial side. The resultant knock knee will be treated by a corrective osteotomy.

if growth does not correct the discrepancy, epiphysiodesis or osteotomy may be performed at the appropriate age. Occasionally an infection near the epiphysis may have the opposite effect and overgrowth will result. This is usually a temporary effect which is corrected spontaneously.

6. *Involvement of adjacent soft tissues* may result from extension of the bone disease. Thus a pyothorax can follow osteomyelitis of a rib; or intra-pelvic abscess and intestinal fistulae complicate infection of the pelvic bones.

7. *Late complications* of a healed acute lesion may occur. The focus may remain healed for months or years and then flare up or cause new lesions elsewhere. This is particularly true when there is severe trauma such as a fracture in the area.

8. Most commonly acute osteomyelitis, particularly if early treatment has been delayed, gradually sub-sides into a chronic infection.

CHRONIC OSTEOMYELITIS

Chronic osteomyelitis is almost always the end stage of a preceding acute infection. Rarely such a low grade lesion may develop primarily and very occasionally may exist with no symptoms at all.

Sometimes a chronic infection of bone will heal spontaneously, particularly after sequestra have been discharged. When this happens, the patient may be cured, or there may be an exacerbation later on. Usually, however, healing is only partial and a low-grade activity of the infection persists. This can be so slight that the patient is troubled only intermittently with mild pain and aching. On the other hand, there may be massive involvement of an entire bone with the formation of multiple sinuses which drain constantly. Soft tissue changes due to impaired circulation, persistent chronic infection, and edema, may be associated. If the infection is extensive and of long standing, the patient will show mild to profound anemia and cachexia.

The changes visible on the x-ray vary as greatly as the clinical picture. There can be anything from a localized bone abscess surrounded by sclerosed margins (so-called "Brodie's abscess") to destruction of an entire bone with multiple sequestra and many abscesses. In general, there is always a combination of destruction of bone and formation of new bone.

Differential Diagnosis.—Although the diagnosis of chronic osteomyelitis is usually obvious, the extreme variability in the appearance of this disease occasionally leads to confusion.

A condition which is frequently mistaken for a small focus of infection is *osteoid osteoma*. This lesion is characterized by severe constant pain and well localized exquisite tenderness. The overlying soft tissues may be swollen and warm, but they are never red. The roentgenographic appearance is typical. The small nidus is usually visible as a round or oval translucent area with a dense center. The whole is surrounded by hypertrophied regional bone. Although the symptoms and roentgenographic appearance are so reminiscent of osteomyelitis that for years this lesion was confused with the sclerosing osteomyelitis of Garré, the differential diagnosis is not difficult. Patients with osteoid osteoma never have systemic symptoms. They have a normal temperature and white count, and are not ill. Complete excision of the nidus gives immediate and permanent relief. Cultures of the material removed are always negative and the pathologic examination is diagnostic. *Myositis ossificans*, especially when the onset is gradual and attended by low-grade fever,

may be confusing. Later when a tender mass can be palpated in the soft tissue and irritation of the periosteum has stimulated new bone formation there may be even more question. There will of course be no pus demonstrable and, if the lesion is immobilized, it will gradually organize and then recede. *Tuberculous osteomyelitis* is usually associated with tuberculous involvement of a joint. Rarely it is primary in the metaphysis of a long bone. Although the diagnosis can usually be supported by the presence of other acid-fast foci, it is sometimes necessary to wait for tissue examination and guinea pig inoculations. *Sarcomas of bone* are not infrequently mistaken for osteomyelitis and vice versa. Sclerosing tumors and those which have excited much reactive new bone formation are particularly difficult. Here again if pus cannot be obtained by aspiration, pathologic examination may be necessary to establish the diagnosis. *Metastatic lesions* such as those of neuroblastoma or the blood dyscrasias may produce osteolytic foci but their appearance is rarely such as to be confused with osteomyelitis.

Treatment.—Since the clinical picture will depend upon the severity of the disease and the stage at which the particular patient is seen, it is again to be emphasized that no standard treatment can be used for all patients, but the principles of treatment are the same for all.

In the chronic form of osteomyelitis, chemotherapy alone does not suffice. It must be considered only as a powerful adjunct to adequate surgical treatment. Since this surgery is elective (except for the acute exacerbations which are handled in the same manner as a primary acute osteomyelitis) it need not be undertaken until the patient is in good general condition. Often extensive preparatory treatment is necessary before the anemia has been corrected. Attention to this phase of management will increase the success of later surgery.

In this case the object of the operation is twofold, to eradicate as completely as possible all infection, and to provide good soft tissues for closing the wound. This means that all scars and sinus tracts should, wherever possible, be excised. Pre-operative x-ray of these tracts injected with radio-opaque material is a useful procedure in planning the surgery. The underlying bone pockets filled with granulation tissue and/or pus and often containing sequestra must be widely unroofed and completely cleaned out (Fig. 65). The osteotomy should be extended from good bone above to good bone below. The defect is then "saucerized" so that a shallow crater is formed into which soft tissues may collapse. If the lesion seems relatively inactive and the osteotomy fairly complete, it is often possible to mobilize the adjacent soft tissues sufficiently to permit primary closure. A good many such wounds will heal per primam. Again, if there is any doubt about the advisability of closure, or if the defect is too great to close, the wound can be packed open and closure undertaken as a second stage operation. In either case splinting is used if necessary because of bone weakened by disease or operation, and parenteral penicillin is continued. Nothing is to be gained by the local instillation of chemotherapeutic agents.

The most significant recent surgical advances in the treatment of chronic osteomyelitis have to do with the management of bone and soft tissue defects. In children regeneration of large amounts of bone is to be



Fig. 65—Following the extraction of an abscessed tooth, an 11 year old girl had a severe chill and developed pain in the left hip. High fever was rapidly followed by delirium, coma and convulsions. Hemolytic *Staphylococcus aureus* was demonstrated in the blood and spinal fluid. She was treated with serum (antibiotics were not yet available) and recovered. During convalescence she developed multiple soft tissue abscesses and extensive osteomyelitis of the left femur. No treatment was given except to lance the abscesses. The admission roentgenogram (left) shows that the head and neck of the femur have been completely destroyed. The stump of the femur is dislocated and the entire bone is massively diseased. Shaggy irregular involucrum surrounds the remainder of the shaft, the outlines of which are clearly marked by cortical sequestra. Three years and six operations later (center) there is little evidence of active disease in the club-shaped bone, but there is a persistent soft tissue sinus. This was excised again and finally healed. Eighteen months later the stump of the femur was denuded and reduced into the acetabulum. Penicillin was used, there was no flare-up of infection, and the hip is now stable, as shown (right). Leg length inequality was rectified by the removal of 2 inches of bone from the supracondylar region of the opposite femur. (The bone removed was split in three pieces and used as an intramedullary peg and onlay grafts). In the course of this patient's disease she has had pyogenic involvement of three major joints and eight different bones as well as numerous soft tissue abscesses. Now, nine years after her initial disease, and after nineteen major operations she is clinically well, walks without a limp, and is able to pursue a normal life. Amyloidosis is demonstrable with the Congo red test.

expected, but a defect in an adult bone usually does not fill in spontaneously. Furthermore, even when infection in the bone has been controlled, adequate healing will not occur until a good soft tissue covering

has been provided. In the management of these cases chemotherapy has been invaluable, for it has permitted the successful use of plastic procedures for bone, muscle and skin which previously gave difficulty.

All of these procedures are secondary to eradication of the bone disease by an adequate partial osteotomy. All are less successful in hematogenous osteomyelitis than in the relatively more indolent infection which results from compound wounds.

Soft Tissue Repair.—When the skeletal defect is not sufficient to weaken the bone, and when it is situated so that soft tissues can obliterate the cavity, primary or secondary closure is usually all that is necessary. Thin, adherent scars can be excised, and, by undermining the adjacent skin and subcutaneous tissue satisfactory closure can be effected. Larger skin defects can often be handled by the use of double pedicled flaps. Relaxing incisions are made on each side parallel to the line of closure and 3 to 4 inches from it. By undermining these strips of skin they can be shifted to cover the gap left by the excised scar and the resultant defects covered with dermatome grafts. This technic is particularly applicable to areas like the front of the shin where there is little soft tissue. Irregular defects can often be covered by the rotation of a single pedicle flap from adjacent skin. When very large areas must be covered by full-thickness skin, one must resort to cross-leg flaps or abdominal pedicles transferred gradually. In general it is better to have the soft tissue work completed and in good condition before anything is done to restore the weakened bone. This obviates the danger of breakdown from post-operative edema.

Bone Repair.—Where there is a large defect in the bone some way must be found to obliterate it. Before the advent of the antibiotics the only possible course was to pack the wound and allow it to granulate in from below. While this procedure frequently results in healing, it is tremendously time-consuming, is often attended by complications, and produces unsatisfactory scars.

Fairly rapid healing may sometimes be secured by the use of *muscle flaps*. If the bone defect is shallow, surrounding muscle can be shifted without radical displacement. If there is a deep rigid walled cavity which cannot be excised without sacrifice of too much bone, it may be possible to form a muscle pedicle which can be drawn into the hole in the bone. This procedure is especially satisfactory when there is an ankylosed joint so that diverting the muscle does not interfere with function. Careful attention must be given the nerve and blood supply of muscle so employed.

When such an approach is not feasible, either because of lack of available muscle or because the bone has been weakened too much for useful function, *bone grafting* can be employed. Grafts may be used to strengthen a bone weakened by wide osteotomy. In this case a simple onlay graft, applied through an incision as far as possible from the site of the original infection, and held in place only by the overlying muscles will usually suffice (Fig. 66).

The use of *multiple chip grafts* to fill deep cavities in regions such as the upper tibia or lower femur has been extremely successful in the management of infection resulting from compound wounds. This is sometimes done at the same time as the soft tissue revision, but the uncertain

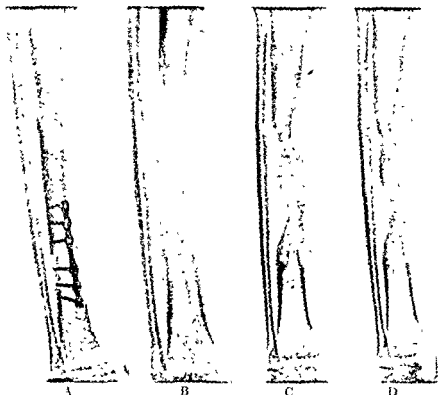


Fig 66 — A boy of 15 had a severely compounded fracture of the lower third of the right tibia. An open reduction with plating was performed the same day. Soft tissue slough and extensive osteomyelitis resulted. A, Admission roentgenogram made twelve weeks afterwards shows chronic osteomyelitis with subperiosteal ossification along the whole bone. There is nonunion of the fracture, absorption about the metal, and sequestration of the entire middle third of the shaft. B, The first postoperative x-ray, after removal of metal and dead bone, shows well the extensive involucrum. C, Shows the amount of spontaneous regeneration in three months, with nonunion at the upper third. Meanwhile the wound had been closed with split thickness skin grafts (see Fig 67). Iliac grafts were onlaid through a posteromedial incision, and D, taken six months after admission, shows beginning union. Penicillin was used for the first six weeks and in conjunction with his subsequent surgery.

success of the one stage operation led to the development of a different technic using *split-thickness skin grafts* as a temporary dressing.

This procedure is simple and is applicable to a wide variety of cases. As with the other methods its success depends upon an initial adequate removal of infected bone and scar tissue. Although some surgeons apply

the graft immediately, it is probably safer to pack the wound for five to seven days to allow a thin bed of granulation to form. The limb is of course immobilized and antibiotics used freely. At the time of the first dressing, if the wound is clean, a thin dermatome graft is applied to the entire raw area. Some soft material, such as glycerin-soaked cotton is employed as a stent so that the graft is held firmly to all portions of the irregular cavity. Even in the presence of mild infection a majority of these grafts will survive, with resultant early and complete healing. An



Fig. 67.—Same case as Figure 66. The admission photograph (*left*) shows the granulating wound. In the center is the sequestered middle third of the tibia bathed in pus. The top half of the plate is exposed. After sequestrectomy the wound was packed with petrolatum gauze and a cast applied. One month later the entire area was covered with split thickness grafts. The picture (*right*) shows complete healing in three weeks. (The irregular appearance is due to variations in pigmentation in the scars of this Negro patient.) Two months later bone grafting was performed (see Fig. 66). The final step will be excision of the split graft and thin scar and replacement with full thickness skin.

interval of two to three months is then allowed during which time the surrounding skin loosens up and the size of the pocket decreases somewhat. If the area covered by the dermatome graft is small, shallow, and not subject to trauma, no further surgery is needed. With larger scars, especially those which fill pockets, the contracture of scar tissue, vascular changes, and subsequent circulatory difficulties lead to break-down of the graft and flare-up of infection. In these cases the split-thickness graft is considered only as a temporary dressing (Fig. 67).

Two to three months after healing, the third or definitive stage of surgery is undertaken. The split-skin graft is excised *in toto*. The type

out it. The wound is then closed with full-thickness skin obtained by one of the methods already mentioned. Unless it is absolutely necessary a drain is not used.

Unfortunately it is still true that one sees some instances of old neglected osteomyelitis. These patients have usually had drainage for many years. The bone is very sclerotic and the soft tissues, with their extreme



Fig. 68 — A man of 52 had had osteomyelitis of the right tibia for thirty-nine

circulatory changes, are unsuitable for any type of reconstruction. Pockets may become partially epithelized and this condition favors the persistence of drainage. Not infrequently such a situation leads to the development of squamous cell carcinoma in the sinus tract. For most of these cases amputation is the only solution (Fig. 68).

One further complication of chronic osteomyelitis which is also disappearing as a result of modern therapy is the development of amyloidosis. This distressing systemic disease is prone to occur in any patient with a long-standing chronic infection. With the lessening of the incidence of osteomyelitis in general, and the shortened morbidity from chronic osteomyelitis, amyloid disease from this cause is becoming rare.

SUMMARY

1. Acute osteomyelitis is best treated by penicillin which is to be combined with surgical drainage if localized suppuration is evident.

2. Chronic osteomyelitis is treated by complete excision of all diseased and scarred tissue, followed by obliteration of defects and closure of the wound with healthy soft tissue. Antibiotics are an invaluable adjunct to the surgery of osteomyelitis.

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BONE TUMORS

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In this clinic it will not be possible to include a discussion of all types of tumors which may affect bones. These tumors may be subdivided for purposes of classification into those of *nonosseous* origin and the tumors which are related to *osteogenesis*.

Tumors of nonosseous origin would include:

- Endothelial myeloma (Ewing)
- Multiple myeloma
- Fibrosarcoma
- Neurofibrosarcoma
- Synovioma
- Hypernephroma (metastatic)
- Metastatic carcinoma
- Angiosarcoma

Tumors related to osteogenesis or bone formation would include:

Benign

- Osteochondroma or benign exostoses
- Osteoma (these arise from membranous bone)
- Bone cysts
- Benign giant cell tumor
- Chondroma or benign chondromyoma

Malignant

- Chondrosarcoma
- Osteoblastic osteogenic sarcoma
- Osteolytic osteogenic sarcoma

There are other specialized tumors or subdivisions of some of the above osteogenic sarcomas which we will not undertake to describe or to include in this clinic.

DIAGNOSIS

The successful treatment of any malignant tumor must depend upon a diagnosis being made soon enough after the onset of symptoms to permit local excision or amputation before metastatic spread has taken place. Errors in diagnosis have resulted in suffering and death to countless thousands of patients whose lives might have been saved if the first ex-

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amining physician had been more keenly alert or more thorough in his examination.

The burden of the responsibility in diagnosis and treatment of tumors of bone is too great for one clinician. Determination of the nature of the tumor, insofar as is necessary to decide that it is either benign or malignant, should be made by a team of competent physicians consisting of (1) a clinician who provides information which includes an accurate history and the findings obtained in a careful physical examination, (2) the roentgenologist who has made a careful roentgenogram, and (3) the pathologist who has made a careful microscopic examination of the tumor. The findings of each of these three members of the diagnostic team should be summarized and compared, and a decision reached as to the nature of the tumor.

No tumor which may be malignant should be subjected to treatment, either radical or conservative, without a biopsy and microscopic examination of tissue from the tumor. It is unfair, however, to expect the pathologist to make an accurate diagnosis from a very small segment of tissue which may not even be representative of the tumor as a whole. An adequate amount of tissue should always be obtained at the time of the biopsy. The pathologist should also have the benefit of a report of the x-ray findings, the history and the information obtained from the physical examination of the patient. A conference between these three members of the diagnostic team, with a review of all of the information that is available, is an ideal method of reaching an agreement that will greatly improve the statistical average of correct diagnoses.

The history of the patient who has a tumor is of the greatest importance. There are certain rather characteristic points to be remembered: (1) *Benign tumors rarely produce pain.* (2) *The malignant bone tumor does produce pain, which may be intermittent in the early stages of the disease process, but is most often severe at night.* (3) *The benign tumors grow slowly.* (4) *The more malignant the growth, the more rapid it is likely to be.* (5) The history of injury must not be ignored. (6) Fracture through a bone tumor or confusion of a swelling formed by neoplastic tissue may greatly stimulate the growth of the tumor cells and their tendency to invade or metastasize. (7) A fracture through a bone weakened by the presence of tumor may greatly change the x-ray and the microscopic findings. (8) *Callus produced by the repair of the fracture may be seen in the roentgenogram or noted in the microscopic section leading to an erroneous diagnosis of a tumor of cartilaginous origin.*

Differential Diagnosis.—In considering a differential diagnosis of bone tumors, we should think of the *osteoid osteoma* which by some is thought to be a chronic low grade inflammation, and by others a definite neoplasm. Regardless of which of these theories is correct, the condition is always localized and does not metastasize. It requires only local excision for treatment. Sclerosing osteomyelitis or an old chronic bone abscess may produce night pain, local swelling, loss of weight, and may lead to an erroneous diagnosis which can be corrected only by biopsy.

Enlargement of lymph glands adjacent to the region involved by a bone lesion may be misleading. The hyperplastic lymph gland which becomes enlarged because of a regional low grade infection has been erroneously thought to show malignant changes when reviewed under the microscope.

PROGNOSIS

Prognosis in tumors which arise in the bones is most difficult. *Multiple myeloma* may be confined to a single vertebral body. X-ray therapy has been found to be palliative, resulting in initial repair, but there are no accepted cases of a cure of a patient with this disease. The majority of these patients die within less than five years after the diagnosis has been made. The *Ewing tumor* or endothelial myeloma, as it is sometimes called, has been fatal in all proved cases which I have treated or have observed. This has been true regardless of whether the primary lesion was treated by local excision, amputation, or by x-ray alone. *Synoviuma* is slow growing and slow to metastasize. Perhaps for the same reasons diagnoses have not been made in most instances until the tumor became quite large. A prognosis of less than five years' survival must be made in the case of each of these tumors regardless of whether it is treated by local excision or by amputation. *Fibrosarcoma* is also slow growing and slow to metastasize and, when it is treated by extensive local resection or by amputation, prognosis for complete cure may be considered to be fair.

The *osteoblastic osteogenic sarcoma* possesses the ability of forming bone within the tumor tissue itself. Thus, bone will form in the metastatic lesions in the lungs, liver or elsewhere in the body. This is a highly malignant tumor that produces sclerosis in the bone as a result of the tumor bone formation. Early diagnosis and amputation offers the best possibility for survival.

The *osteolytic osteogenic sarcoma* does not produce bone, although bone formation may be present if the growth of the tumor raises and strips periosteum. This is merely a reactive type of bone but it sometimes makes the diagnosis more difficult. Extensive regional resection or amputation is the treatment of choice.

ILLUSTRATIVE CASES, WITH NOTES ON TREATMENT

The following cases are presented to illustrate certain points in diagnosis and treatment of bone tumors:

CASE I.—T. D., a boy aged 16, was seen by me in consultation because of a marked tumor-like enlargement of the right thigh. Roentgenograms showed marked bone formation in the muscles about the right femur. Osteogenic sarcoma had been suggested as the probable diagnosis by the examining physician and amputation was contemplated. This patient gave a history of an injury while playing football. The roentgenograms which showed bone also demonstrated typical longitudinal trabeculation within the bone tissue (Fig. 69). The bony

mass was attached to the femur by a wide pedicle which was not as long as the mass of bone itself. There was only slight tenderness. I made a diagnosis of myositis ossificans, a relatively mild lesion which responds to conservative treatment of x-ray therapy and immobilization. This patient made a complete recovery and subsequently was captain of the football team in one of the leading universities.

Comment—Although this particular case had a happy ending, I have had occasion to see the amputated leg of another teen-aged boy who was thus crippled for life because of the erroneous diagnosis of a sarcoma when the lesion was nothing more than myositis ossificans. These cases



Fig. 60 (Case I, H. T. D.)—Myositis ossificans which was erroneously thought to be sarcoma.

are referred to in the hope that we may emphasize again the necessity of making an accurate diagnosis before undertaking any treatment.

CASE II—F. E. J., a young man of 19 years, noted pain and swelling just

1 by 2 cm. in area. In the lateral view the periosteum was seen to be elevated on

the posterior tibial cortex (Fig. 70). The inguinal node was removed and microscopic examination revealed moderate hyperplasia. The differential diagnosis of the lesion in the tibia seemed to be between sarcoma and chronic bone infection. At operation pus was evacuated from a typical Brodie's abscess, and the defect curetted and instilled with 100,000 units of penicillin. The wound healed uneventfully and without drainage.

Comment.—This patient has made a complete recovery. Lesions similar to this, however, have been erroneously diagnosed as osteogenic sarcoma and the patient subjected to needless amputation. Such a dreadful mistake will not be made by the surgeon who insists upon biopsy before any treatment is planned.



Fig. 70 (Case II, F. E. J.).—Central medullary lesion with periosteal new bone formation. Malignancy was suspected and patient was referred to an amputation center. Surgical exploration showed this to be a chronic bone abscess.

CASE III.—L. G., a girl aged 11 years, was first seen by me at the University of Chicago Clinics. She came complaining of pain and swelling just below the right knee of only two or three weeks' duration. Roentgenograms revealed a diffuse increase in density in the bone of the tibia just below the upper epiphyseal cartilage plate with ossification of tumor tissue extending lateral to the cortex of the tibia (Fig. 71). A diagnosis of osteogenic osteoblastic sarcoma was made. Biopsy with frozen section confirmed the diagnosis and a mid thigh amputation was carried out. (See Figs. 72 and 73.)

This patient has been seen at intervals since that operation, and today, at the age of 24 years (thirteen years after the amputation), she is married and is using an artificial limb with considerable skill and dexterity, and enjoying the best of health.

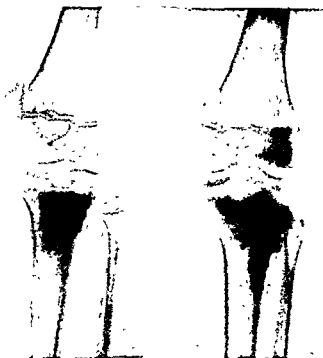


Fig. 71 (Case III, L. G.) —The dense bone formation near the upper end of the tibia of an 11 year old girl, with ossification extending into the surrounding soft tissues, led to a diagnosis of osteogenic osteoblastic sarcoma.

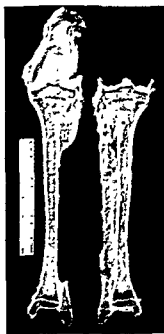


Fig. 72 (Case III) —These longitudinal sections of the tibia reveal the tumor mass on the lateral side of the proximal end of the bone and hard, white, sclerotic tumor bone within the shaft distal to the epiphyseal line.



Fig 73 (Case III).—Osteogenic osteoblastic sarcoma, showing true tumor bone formation. Note the conspicuous condensation of the poorly formed trabeculae. The spaces are filled with metaplastic fibroblasts containing mitotic nuclei. This is a very malignant, rapidly metastasizing tumor which is highly resistant to x-ray therapy.



Fig. 74 (Case IV, A. S.).—*Left*, Roentgenogram (1937) showing what was thought to be a benign fibrocystic lesion of the proximal end of the femur. This lesion was cleaned out surgically and the tissue was thought to be benign when examined grossly and microscopically. *Right*, Roentgenogram of the same hip in 1940, three years later. The lesion has become markedly destructive. A pathological fracture has occurred. Microscopic sections now show a high degree of malignancy (see Fig. 75). Death from metastases occurred six months after this roentgenogram was made.

Comment.—No bone tumor is more malignant or carries a higher incidence of metastases and early death than does the osteogenic osteoblastic sarcoma. The excellent result obtained in this case with what appears to be a complete cure must be credited to the fact that a correct diagnosis was made within a short period of time after the onset of symptoms, and the amputation with complete removal of the malignant lesion was carried out promptly and at a level sufficiently far removed from the primary tumor.

CASE IV.—A. S., a man 29 years, was operated upon by me at the Albert Merritt Billings Memorial Hospital in November 1937, with a diagnosis of fibro-



cytic disease of the upper end of the left femur (Fig 74, A) Pathological reports after examination of the tissue microscopically seemed to confirm the impression

Cook County Hospital on January 17, 1942, of bronchopneumonia and general metastases.

Comment.—A more accurate diagnosis in 1937, followed by resection of the entire upper portion of the femur and replacement of the resected femoral trochanters, neck and head with a massive bone graft, in all probability would have eliminated the neoplasm and preserved the life of this patient.

CASE V.—D. M., a man aged 21 years, was seen because of pain and swelling in the region of the left shoulder. The patient described an incipient onset with slight aching and then swelling and stiffness in the left shoulder beginning five months before he came to our office



Fig. 76 (Case V, D. M.).—Osteoblastic osteogenic sarcoma of the proximal end of the humerus. Note the sclerosing density and the radial formation of the new trabeculae

Physical examination revealed a thin, almost emaciated-appearing young man who had obviously lost much sleep and was suffering pain. There was marked swelling of the upper half of the upper arm and the region of the left shoulder joint. This mass was firm and tender. The infraclavicular lymph nodes were enlarged and hard. All motions of the shoulder were limited.

Roentgenograms of the left shoulder revealed marked bone changes consisting of increased density, with new bone formation all about the old cortex (Fig. 76). Sharpey's fibers were well ossified, creating a stellate or radial trabecular formation. The appearance was typical of *osteogenic osteoblastic sarcoma*.

The probability of survival for more than two or three months was considered to be poor.

Comment—A correct diagnosis should have been made within a few weeks of the onset of symptoms. Five months is too long to defer treatment if we hope to save the life of a patient afflicted with osteogenic osteoblastic sarcoma.

CASE VI—C S, a man aged 28 years, consulted me on January 22, 1942 because of pain in the right arm near the site of insertion of the deltoid muscle. Roentgenograms made elsewhere had been interpreted as showing no pathologic change. A study of new roentgenograms and a re-study of those made previously showed slight but definite erosion of the outer cortex of the humerus in the middle third. There was also a faint shadow of periosteal new bone formation.

The patient had complained of some discomfort in this arm for approximately

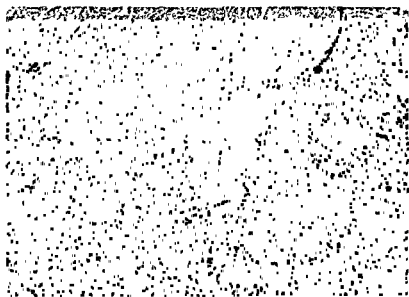


Fig. 77 (Case VI, C S) —Photomicrograph ($\times 95$) of microscopic section of tissue from the tumor of the right humerus. The cellular elements are largely fibroblasts. This is a fibrosarcoma of only a moderate degree of malignancy.

one year. The slight changes noted in the bone, added to the finding of a palpable small zone of induration in the tissues about the humerus, indicated that this lesion was of a rather low grade of malignancy, if it were a malignant tumor. Biopsy was carried out (Fig. 77) and frozen sections showed the lesion to be a fibrosarcoma with a sufficient number of mitotic figures in the fibroblastic cells to make radical treatment imperative. Because tumors of this type are known to be unusually slow to metastasize or to spread by extension, an attempt was made to remove it by regional resection. The middle third of the shaft of the humerus was removed together with all attached surrounding tissue, including some normal-appearing muscle and fascia. The defect in the humeral shaft was repaired with bone from the tibia. The patient made an uneventful recovery. The tibial graft united firmly at one end and by good fibrous union at the other, and he had excellent use of the arm for a few months.

Roentgenograms made about six months after operation showed beginning

destruction of the graft, indicating local recurrence of the tumor. A large, hard, axillary lymph gland also was noted at this time and this was removed and found to contain malignant tumor cells. It was obvious, therefore, that the only chance of saving the life of this patient was to do a complete thoracohumeral fore-quarter amputation, removing all axillary lymph glands along with the extremity. This operation was carried out October 29, 1942. At the present time, approximately six years from the time of this amputation, the patient, now aged 35 years, is entirely well and has become so dexterous in the use of his left arm that he holds the same position, and carries out satisfactorily all the duties thereto, which he held before the appearance of this fibrosarcoma and amputation of the arm.

Comment.—Although fibrosarcoma is known to be a slowly growing, slowly extending, and slowly metastasizing lesion, once it has spread to



Fig. 78 (Case VII, D. R.).—Extensive skeletal metastases from carcinoma of the breast. There is no evidence of bone repair or of reactive new bone formation

the regional lymph glands only the most radical surgery such as was carried out here offers any reasonable opportunity for the preservation of life.

CASE VII.—D. R., a white woman of approximately 60 years of age, developed pain in her thigh seven and one-half years after the removal of a breast following a diagnosis of adenocarcinoma. She survived three and one-half years after the first skeletal metastases could be demonstrated in roentgenograms. (See Fig. 78.) For most of this period of time she was kept reasonably comfortable and the lesions repeatedly retrogressed following x-ray therapy.

Comment.—Although generalized skeletal metastases of this type of carcinoma can never be cured by x-ray therapy, this treatment is of the greatest value from the standpoint of comfort for the patient and prolong life, as in this case, for a period of several years.

THE PAINFUL SHOULDER

FRANK H. HERGES, JR., M.D.*

THE shoulder, as a functional unit, is subject to the disabilities of similar units. However, after elimination of the fractures, dislocations, infections and arthritides, there remains a narrow group of conditions peculiar to this region. This group is only vaguely classified and understood by the average medical practitioner. We are concerned with this group in an effort to classify and simplify it for the practicing physician.

ANATOMICAL CONSIDERATIONS

Many standard textbooks and publications reveal detailed accounts of the shoulder region. Certain points can well be emphasized.

1. The shoulder possesses the widest latitude of motion in all directions with a position of rest near the extreme, *i.e.*, adduction and internal rotation. The major portion of the work of the extremity can be, and is performed in this position, with little muscular demand on the shoulder.

2. The joint is surrounded by a fibrous capsule into which the tendons of the short muscles, the supraspinatus, infraspinatus, subscapularis and teres minor, are intimately blended, as well as to each other, to form a single unit, the musculotendinous cuff. The conception of rounded, discrete tendons, similar to a finger flexor, is not to be entertained in this region. The long head of the biceps is such a rounded tendon, enclosed in a sheath which is essentially a prolongation of the joint, open proximally and closed distally. A portion of the tendon, varying with position of the shoulder, extends through the joint. The joint capsule, in a position of rest, shows a large inferior fold, thus allowing for a wide range of motion.

3. The shoulder occurs at the summit of the trunk with sharp recession to the midline. As a result, the muscles of elevation are denied a mechanically sound proximal base. Leverage is added by a projecting bone mass the acromium plus a projection for insertion, the tuberosities. The result is a comparatively weak function, plus a close bony tolerance as the extremity approaches a right angle in lateral abduction. The motion of abduction is said to be initiated by the supraspinatus, carried through by the deltoid and continued by rotation of the scapula. However, the supraspinatus must maintain a tense, although not contractile state for deltoid function; so the deltoid for scapular function.

4. The external surface of the joint, its capsule and musculotendinous cuff, is covered by a bursal or gliding surface, the subdeltoid bursa. Anatomically divided into several compartments, it must be regarded as a functional unit to facilitate passage beneath the acromium and deltoid.

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GROUP SYMPTOMATOLOGY

Patients presenting themselves to a clinic for observation have a superficial and disconcerting similarity of symptoms and findings.

1. Pain in the shoulder region centering about the insertion of the delto d, varying in intensity from bearable to excessively severe, but constant and disabling, with the worst period at night

2. Inability of the extremity to function in the elevated, abducted and externally rotated position, with comparatively free movement of anterior elevation.

3. A lack of major trauma

4. A lack of general symptoms and signs

5. An age group in the latter period of life

- 6 Engagement in a manual occupation frequently throwing strain on the shoulder

Too frequently observation stops at this point with a vague diagnosis of arthritis, neuritis or subdeltoid bursitis. The result of such a diagnosis is exceedingly poor with much dissatisfaction for the individual patient.

SUBDELTOID BURSTITIS

This phrase has served as a catch-all for the group for many years. A though the possibility of a pure bursitis is acknowledged in the literature, there appear no reports of its occurrence. Presumably this bursa could become inflamed through trauma, infection, or the ill-defined toxic or arthritic factor. Surgical and anatomical reports show inflammation of this structure and later fibrosis of its wall. However, they invariably relate this to pathology in the adjacent musculotendinous cuff or joint. It is believed that irritation of the bursa and resulting inflammation are productive of symptoms and signs. At the onset there would be pain by distention of the bursa and the inflammatory process. This pain would increase with elevation of the extremity through compression as the tuberosity approaches the acromium. Muscular spasm would be noted which, with the pain, would prevent active abduction and rotation. Passive motion should be free, with no evidence of muscle loss of power. There should appear some sensitivity to pressure over the bursa and perhaps a sense of fullness. As the condition extends in time, and subsides, the wall of the bursa becomes thickened. This fibrosis appears as the source of mild chronic long-lasting pain, mostly noted after extended usage of the shoulder. The possibility of obliteration of the bursa, and consequent restriction of motion at the shoulder, has been noted. There appears little investigative background to indicate that this does occur. Excision of the entire bursa has been performed with little restriction in shoulder function.

Treatment.—Treatment has, for the most part, been directed at underlying pathology rather than the bursitis. Certain general measures have of necessity been applied to the entire region without regard for structure.

Heat.—In the simple form heat has been found of little value either for relief of pain or improvement of the course of the disease.

Diathermy.—Much has been written concerning the value of this form of heat and it is unquestionably widely used. The value has been seriously questioned and it is evident that many patients, especially in the acute stages, are more uncomfortable with its use.

X-ray Therapy.—There are a variety of conflicting reports, extending from 70 to 90 per cent quick relief in acute cases to no benefit in any case. Many papers lack exact diagnostic detail and criteria of benefit. It is admittedly of little value in long-standing cases. Personal experience with this form of treatment has been disappointing and it is seldom used.

Puncture and Irrigation.—The successful and rapid relief of pain in acute cases through introduction of several large bore needles into the bursa and irrigation of the structure with saline, has been reported by groups of workers. Other groups have been unsuccessful in irrigation, but have used multiple fan-shaped punctures with equal satisfaction. More recently a widely expressed opinion prevails that puncture of the bursa alone is insufficient, and that relief is secured through puncture of the musculotendinous cuff, without irrigation of the bursa. There appears to be general belief that puncture in some form gives quick relief of pain in most acute, severe, painful conditions.

TENDINITIS

This division of cases appears more often in males in the older age group and in manual occupations. One phase of the condition presents an acute pain of sudden onset and great severity, reaching a peak at which time it is poorly influenced by narcotics. There is great muscle spasm and resistance to motion at the shoulder, with the extremity held in adduction and internal rotation. Constant slight shifts of position in an unsuccessful attempt to find comfort are notable. No muscular weakness or restriction of motion by adhesions appears. The difficulty of testing at this stage is apparent and results are apt to be unsatisfactory. Although the site of pain is referred to the insertion of the deltoid, localized tender areas are found about the tuberosity. Trauma appears in this picture in an indefinite manner; usually no clear-cut incident is remembered.

X-ray may reveal small radiopaque bodies near the tuberosity. The bodies may be single or multiple, and must be sought for in various views, often including fluoroscopy, to prevent hiding behind bony structures. At times, in the absence of these bodies the cortex of the tuberosity may be roughened, excavated or eburnated. At other times negative films are noted.

This is accepted by most groups as a tendinitis of the short muscles. Through wear and tear, trauma, overuse, aging, and perhaps some toxicity, the fibers appear hyaline and small ruptures occur. At the site of

rupture cavities develop and fill with débris. This débris may become a site for the deposit of calcium salts and so appear in an x-ray. Frequently the tension in these cavities increases and is felt to be the origin of the acute painful episodes. The projection and roughness of the degenerative area produces an inflammatory change in the adjacent subdeltoid bursa, which in turn adds to the clinical picture. With the pain and muscle spasm, plus the property of increasing tension by elevation, the characteristic posture is induced. The tender spots noted on examination are thought to be the superficial evidence of the location of points of tension and degeneration in the tendon fibers.

It is believed that, if untreated, the cavity ruptures into the bursa with relief of acute pain and absorption of the calcareous deposits. A chronic stage is then entered with bursal inflammation persisting and gradually resolving. The degenerate changes in the tendon are persistent as well as a certain amount of bursitis. Symptoms may subside, although usually some discomfort in the use of the shoulder remains, especially in the extremes of abduction and rotation. The time interval varies from a few weeks to many months.

The acute phase appears to be only a part of a progressive degenerative process which exists before and continues after. Certainly calcareous nodules, occasionally bilateral, are found in shoulders which have not been subject to an acute episode. Sooner or later these quiet processes erupt into an acute phase and may recur. The amount of disability in the chronic state must depend on the amount of fibrosis and persistent inflammation in the tissues and bursa. This can be severe with occasionally actual bony plaque formation. The general pattern of aching on heavy use with pain in the extremes of motion is retained despite its varying intensity.

Many workers feel that the acuteness of the condition can be approximated by the outline of the calcareous shadows, a smooth globular outline seen in the acute stage and a more fuzzy, irregular shadow in the chronic. Others have demonstrated surgically the acute material as semi-fluid, wet, chalky, with the chronic as drier, cheesy material.

Although great attention has been paid to these calcareous shadows, it is clear that both the acute and chronic phases may exist without them. Changes in the outline of the cortex of the tuberosity may mark a fairly long-standing condition. At other times it exists with symptomatic exactness and is relieved by similar measures, with no visible x-ray findings.

In certain cases there remains a fibrous restriction of the joint movements. Although moderately severe, this restriction does not approach the true frozen shoulder. The longer the period of resolution, the more severe appears the restriction of motion. It does not seem necessary to visualize obliteration of the subdeltoid bursa or severe involvement of the joint to produce the findings. Long-continued periods in the position of rest or adduction with an inflammatory reaction adjacent to the joint are quite sufficient to cause some obliteration and adhesion of the loose

dependent portion of this joint capsule. Similar results, under similar conditions may be seen in many joints. With recession of the activity and resumption of use the motility gradually increases.

Treatment.—The reports of treatments have been so varied and often so contradictory that an evaluation offers some difficulty. There is little doubt that in the acute phase pain is severe, to a degree not too often matched, and that the use of narcotics should be approved in adequate dosage. The attempt to continue in manual work, while commendable from a standpoint of courage, can hardly be recommended as a satisfactory adjunct to recovery.

Heat in general has been found of little benefit, either for temporary relief of discomfort or more permanent shortening of the disease course. It is widely used, although many times only for want of a better approach. Cold should be expected to contract the tissues and lessen the tension. In usage the benefit is minimal.

Diathermy has been widely reported as a satisfactory form of treatment and has been credited with causing the disappearance of the calcareous shadows. In the acute phase it is said to increase the patient's discomfort. In carefully evaluated observations there is serious reason to question that diathermy plays a significant part at any stage. It is well understood that in the final stages of most diseases involving a joint, in a stage when recovery depends solely upon resumption of activity, some form of heat and a regular exercise program are of value.

X-ray Therapy. This form of treatment has been mentioned in a previous paragraph. The observations there apply to this group as well. Reports are very contradictory. In well-controlled experiments the conclusion appears that the value is small. It is believed that sufficient dosage and inflammatory reaction may accelerate the spontaneous rupture of the area of tension into the bursa. The anticipation of such a result must expect considerable irregularity in the course of the disease.

Immobilization.—A variety of splints and plasters have been used to hold the extremity at rest in an abducted position. The principle of rest for an inflamed joint and its surroundings has been approved as sound many times and in many conditions. Certainly some benefit as to immediate discomfort can be expected. However, it does not appear to be great and there is little reason to expect relief from tension in the tendon fibers. The use of immobilization has not been general.

Exercise.—Some modification of the pendulum exercises has been widely used in the stage of resolution with benefit. The tendency has been toward securing passive motion of abduction by this means, in an effort to prevent the formation of restrictive adhesions in the joint or bursa. It can only be considered an adjunct to any form of treatment, but as such has proved that it deserves its place.

Relief of Tension.—The most recent and successful lines of treatment are based upon relief of tension in the distended cavity of the musculotendinous cuff. They are essentially three:

1. The awaiting of spontaneous rupture of distended cavities has been

assisted by really large doses of narcotics as well as rest of the extremity, extending into bed rest. This, of course, is merely an effort to make bearable the endurance of a disease phase which is admittedly open to recession. Such a course appears to offer little that is constructive. Personal attempts to follow this have been unhappy and appeared to prolong the discomfort of the patient unnecessarily. Its proponents state that the course of the disease is about the same as with other methods of treatment.

2. The puncture of the distended tendon in the acute phase has offered a high percentage of prompt relief of pain for many workers. The control of pain can be expected in twenty-four to forty-eight hours with an early resumption of motion and little occurrence of restrictive adhesions. The procedure is a simple office maneuver needing little more than an understanding of the objective and of the regional anatomy. Large bore needles are used and aspiration is attempted, but is not considered necessary nor is too often successful. It is felt that direct puncture of the involved tendon is necessary and that securing of calcareous material offers proof of accomplishment.

3. The surgical relief of tension has been very successful. A small incision is directed through the deltoid and subdeltoid bursa opening into and evacuating the distended tendon. It has been advocated as a more certain procedure. Thorough curettage of the involved area was advocated in early reports, but more recently it has been held that simple incision and evacuation are superior.

or a tremendously thickened bursa. These have on occasion been removed by surgery. Such cases are certainly the exception and place considerable strain upon surgical judgment.

In general it is emphasized that this is a long-standing disease. The prognosis as to recovery from any one acute episode and eventual compensation in use of the extremity is excellent. The period from acute phase to resolution is wearing to both patient and physician. The proper use of puncture or surgery may considerably shorten this period.

TENDON RUPTURE

The rupture of the tendons of the shoulder was brought to attention

people. The more common is in the region of the supraspinatus. These rents have revealed these rents in as many as 25 per cent of the cases. It has not approached this number.

The typical clinical picture is as follows:

in the later

period of life and engaged in manual labor. With its onset there is a muscular strain or a fall of not too great severity. A snap in the shoulder region may be experienced. The pain appears at once, but is not severe. Intensity mounts until in a day or so it approaches that of the acute phase of tendinitis. The findings at this stage are similar to tendinitis. A distinctive feature should be weakness or absence of the involved muscle action. However, testing can be very unsatisfactory and confirmation unlikely in the early days. This acute pain subsides in a period of days or a week or so and a varying degree of weakness of the abduction motion can be demonstrated. Passive motion is free, although as the tuberosity passes the acromium a fair degree of pain is felt and guarded against. A tender area over the involved tendon can often be noted. As time passes this disappears and a defect can be palpated in the involved tendon cuff. This latter finding appears regularly listed, but is certainly difficult to elicit and cannot be considered too reliable. The prominent feature remains lack of active abduction with some pain as a result of the injured and indurated tissue. This weakness and defect in the cuff is thought to be permanent. X-ray examination in early stages is negative; in later periods there appears some atrophy and changes about the cortical bone of the tuberosity.

Investigators have found it necessary to predicate a weakening of the tendon fibers through overuse, age, general debility and perhaps toxicity before rupture will occur. This rupture may be partial in that it fails to pierce the full thickness of the musculotendinous cuff. Such an injury may appear as central or on the joint or bursal surface. The rupture may be complete in that an opening is produced from the subdeltoid bursa into the joint space. It must be appreciated that a rent, occurring in a wide tendinous cuff, need not include the entire action of one muscle or may include that of several. There appears to be some divergence of opinion as to the common course of the rent. Many consider the major portion of the rents to occur in a transverse fashion across the tendon fibers, while others consider an oblique or longitudinal rent as the more common. At operation the rent appears as a triangular defect with its base to the tuberosity and its apex towards the acromium. The edges have become falciform and little effort at repair is demonstrated. It is considered as starting as a moderate defect and enlarging to a rather standard maximum size.

The clinical belief that complete loss of abduction is necessary for diagnosis of tear is not well founded. Many cases are encountered with varying degrees of loss in abduction power. Such variance can be readily visualized by appreciation of the conjoined nature of the tendons, the possible positions of the rent and the possibility of retention of function through adjoining intact fibers. It is interesting to note that early stages of tendinitis and rupture are similar in clinical findings. And further, although degenerative changes in the tendon fibers are considered necessary before rupture can occur, the findings of calcareous nodules are not reported. It has been considered by some that rupture is a traumatic

phase of tendinitis, with calcarous material being dispersed at the time of trauma, and thus not appreciable by x-ray. The differential diagnosis between incomplete tears or tears not destroying muscle function to a great degree, and tendinitis remains obscure. In case of rupture more rapid resolution and less tendency to restrictive adhesions is to be expected.

Treatment.—Tendon rupture may be suspected early from a history of trauma but until muscle function can be evaluated the condition must be treated as a tendinitis. Puncture has succeeded in relieving the acute phase, although the rationale is not clear. With a definite diagnosis of complete tear operative repair has been advised. Approach is through an anterior deltoid or acromial incision. The defect is closed with silk material, in fresh cases completely, in older cases by approximating the base to the tuberosity as well as possible. It has been claimed that better closure can be obtained by considering the rent as oblique rather than transverse. This has been adopted in personal cases with anchorage of any small remaining defect directly into the bone surface wherever it may fall. Results give an improved muscle function, but are not complete, some disability remaining. Gradual recovery over a period of months is the rule. It must be appreciated that a pre-existing degeneration still remains and that these patients are generally in the latter part of their useful economic life. Exact estimates of return of function are not available. Frequently a shift of occupation has been necessary.

The incomplete tendon tears require little but pendulum exercises and in later stages some form of physical therapy. Eventual return to usefulness may be anticipated.

PERIARTHRITIS—FROZEN SHOULDER

This condition, dreaded and neglected by the clinician, has often been considered a severe or terminal stage of the preceeding groups. At present it is slowly emerging as a clinical entity. The age group is again in the later years with a greater number of women. Occupation is not prominent as a factor. The onset is slow and insidious. It first appears as a mild aching in the shoulder region, especially after use. Scant attention is accorded by the individual patient. Pain and limitation of motion gradually increase in intensity, reaching a climax in several months. At that time the pain is never quite as severe as in acute tendinitis. It is fairly constant with the worst period at night, preventing sleep. Short remissions of pain for a day or two frequently occur, at which time the patient is hopeful, but never well. Muscle spasm about the shoulder is marked and the extremity is held rigidly to the trunk. Any attempt at active or passive motion is extremely painful and actively resisted. Forward elevation may remain comparatively free. This restriction of motion is based not alone on pain and spasm but on an adhesive ankylosis about the shoulder. Tender areas are appreciated about the tuberosity and the intertubercular sulcus. These areas may vary somewhat in location on examination.

on different days. At its height the condition may be associated with some discomfort in the cervical region and a definite scalenius spasm, with its clinical syndrome, brachial plexus tenderness and radiating pain into the extremity. A generalized swelling may develop in the hand and fingers in the more severe cases.

The level of activity is maintained for several months when the aching and pain gradually subside. The restriction of motion persists, until all discomfort has disappeared. Pain can be produced on a mechanical basis by attempts to force motion, but it promptly subsides with rest. The entire process may occupy six months or a year. With increasing activity the adhesions gradually give way and motion returns.

X-ray findings are negative in the early stages. Later a diffuse atrophy of bone may be observed apparently on a disuse basis.

The origin of this syndrome remains obscure. It appears as an inflammatory process with slow origin reaching a peak and slowly subsiding. There are no general indications as temperature elevation, increased local heat or redness. There appears to be an association in many cases with recent cardiovascular disease. There is no association with arthritic changes in other joints, although both shoulders may be involved.

The disease is self-limiting, giving fairly complete resolution after a long and weary course. Surgical exploration in one group of cases revealed the adhesions to be within the joint space of the scapulohumeral joint. The subdeltoid bursa did not appear as the origin of the restriction of motion. Surgical approach from a different exposure in another group revealed a tenosynovitis, in all stages, of the long head of the biceps. The findings varied from an acute fibrinous stage to a chronic adhesive. This was felt by these workers to be the origin of the adhesive shoulder. It was necessary, however, to postulate the extension through the open proximal sheath into the joint, to explain the restriction of motion. Tenderness over the tendon in the sulcus was a constant clinical finding in these cases.

Treatment.—The treatment of this group has been difficult. Sedation in adequate dosage is necessary. Local heat appears to give some transitory relief but has no influence on the course of the disease. X-ray is of no value. Immobilization gives some relief of pain in acute stages, but appears to favor ankylosis if long continued. Some form of obtaining and maintaining abduction plus graduated active exercises appears to be the most universal and successful mode of treatment. The methods include a sling attached to the head of the bed with the slumping of the patient providing a gradual elevation of the extremity. Adhesive traction with gradually increasing angle of pull has been satisfactory. Manipulation with or without anesthesia to rupture adhesions has been widely used. A general feeling persists that these measures require hospitalization. As the acuteness subsides graduated exercises are inserted into the routine. Discharge is not permitted until a fair amount of painless motion is secured. The exercises are continued for long periods following the hospital discharge.

Such procedures appear successful in relieving the acute pain and shortening the course of the disease, more especially the period of resolution. However, they are not uniformly satisfactory. Frequent attention and sound understanding by hospital and attendants are necessary for this type of traction. Too often it degenerates into a meaningless combination of ropes and pulleys and results are poor. Manipulation requires judgment. If it is performed during an acute phase, the inflammation may be increased and no benefit secured, in fact, the disease may become worse. Pain is more severe, ankylosis more rapid and no form of exercise can be tolerated. The sound principles known for manipulations generally, with repeated episodes rather than one too severe, must be followed. At best several days of increased pain and spasm may be anticipated. This may be combated by the use of injection of a local anesthetic at the time of manipulation, with hot packs afterwards.

It is worthy of note that among those favoring tenosynovitis of the tendon of the biceps as the origin, division of this tendon and reinsertion into the humerus is said to give prompt relief in resistant cases. Results are incomplete as yet in this line of thought.

SUMMARY

It is to be remembered that the painful shoulder as a group is painful, disabling and long-lasting. Eventual return to a fair degree of usefulness by resolution and compensation is likely in the large majority of cases. We do not see cases with histories of loss of function extending over many years. The very elderly would be expected to show the final ravages of the painful shoulder, but in general they do not. A satisfactory adjustment has been made.

Surgery appears to offer the best results in many instances. A careful balancing of the age group of these patients, their frequent cardiovascular associations, the degeneration of the parts involved and their remaining economic usefulness must be made against the expected results of surgery. It does not appear as a field for wholesale cutting. A careful report as to surgical results from the angle of industrial compensation would be useful. Many of this group appear in industry.

* * *

This entire paper is presented as a summary. It is hoped that the interest of the many workers in this field will continue, in order that the clinician may have more to offer his patients.

ACUTE AND CHRONIC BURSTITIS IN THE REGION OF THE ELBOW JOINT

JAMES K. STACK, M.D., F.A.C.S.*

OLECRANON BURSTITIS

WHEN we are confronted with lesions of the bursae about the elbow joint, the one structure that comes to mind first of all is the olecranon bursa. This is a confined sac containing lubricating fluid which lies between the skin over the posterior surface of the elbow and the aponeurosis of the triceps tendon as it attaches to the olecranon process of the elbow. This bursa is particularly vulnerable because of its superficial location and is frequently injured by blows on the tip of the elbow. It is spoken of as "miner's elbow," because in their occupation, miners strike the tip of the elbow against the walls of the shaft in which they are working. In this regard it is akin to "housemaid's knee."

Symptoms.—Following a blow of the elbow against a solid surface there will frequently develop an effusion about the size of an egg over the olecranon process, and the patient will usually have experimented with hot packs and the like for a day or two before he seeks treatment. The egg-shaped swelling will be fluctuant but not particularly tense, and pain will be elicited only on deep palpation of the area. Seldom will there be any limitation of flexion or extension of the elbow and usually no limitation at all of supination and pronation of the forearm. The patient's principal complaint will be localized tenderness and the fact that there is an unsightly swelling over the posterior surface of the elbow joint.

Treatment.—The first move is the aspiration of the swelling to determine what its contents are. Usually an ordinary hypodermic needle preceded by a wheal of novocain will suffice to aspirate anywhere from 6 to 20 cc. of fluid. In the acute traumatic situation this fluid will be definitely bloody. In the more chronic situations it will be amber colored, similar to the fluid that is aspirated from any other chronically inflamed bursa or joint. After the aspiration has been accomplished the bursa will flatten and by the simple expedient of the application of a pressure dressing many of these bursae will not refill with fluid. However, in the application of this dressing it is important not to have it so tight that it will make the patient uncomfortable or obliterate the radial pulse. Many patients to whom the bandage has been applied too tightly will complain of swelling of the lower forearm or wrist and hand; this can be prevented simply by a moderate application of the pressure in the first place. In a number of such patients there will be a minor recurrence of the effusion

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in three to seven days following the original aspiration, and if this occurs a second aspiration is necessary, and maybe a third or fourth. By repeated aspirations and the application of firm but not excessive pressure the bursal swelling will be controlled and the bursitis will be cured. However, in a certain number of patients in whom repeated trauma occurs, especially those who lean on their elbows in their occupation, or knock their elbows in the course of their labors, this acute phase will develop into a chronic villous type of bursitis, which will be cured only by excision of the olecranon bursa. This excision can very well be accomplished under local anesthesia, although general anesthesia is preferable if one is to use a blood pressure cuff on the arm in order to obtain a bloodless field.

Technic of Operation.—The method of choice is a transverse semilunar incision with the pedicle of the flap proximalward. The skin over the olecranon process is then reflected proximally and the bursa will be seen immediately. The wall of the bursa must be dissected from the underlying subcutaneous fat of the skin flap very carefully, so as not to "buttonhole" the skin. The deeper layer of the bursa can then be dissected from the aponeurosis of the triceps tendon over the olecranon process, by sharp dissection. Usually it is impossible to remove the sac without opening it, and in the event that it has to be removed piecemeal one should look carefully for the various elements of lining that may be attached to the triceps aponeurosis or to the subcutaneous fat. The elbow joint is not entered during this procedure and it is not necessary to isolate and retract the ulnar nerve, as the elements of the bursa do not project into the fossa of the ulnar nerve between the olecranon process and the medial epicondyle of the humerus. Closure is accomplished by simply placing a few subcuticular stitches and then closing the skin and applying a pressure dressing from the hand to the midarm and making sure that the arm is kept elevated during the forty-eight hours immediately following operation. After this time movement should be encouraged in the elbow, and at the end of ten days or two weeks there should be no residual limitation of motion, nor residual swelling about the joint.

There are other situations, however, in which the olecranon bursa will develop fluid, either a simple effusion of amber colored bursal fluid or even bloody fluid, spontaneously, and in such situations one must suspect the various vitamin deficiencies or the blood dyscrasias. Patients who have gout can also develop spontaneous attacks of bursitis but this should be diagnosed easily when on aspiration one notes that the contents of the bursal sac are white or chalky in appearance and, under the microscope, the crystals of sodium monourate can be seen in the fluid after it has been centrifuged.

RADIOHUMERAL BURSTITIS (TENNIS ELBOW)

The other common bursal disability about the elbow joint is the so-called radiohumeral bursitis. The radiohumeral bursa is located between

the tendons of the extensor muscles of the elbow on the posterolateral surface of the joint, and the capsule of the elbow over the point where the head of the radius articulates with the capitellum of the humerus. This bursa is not a constant one, and many investigators have failed to find a well-defined bursa at this point in all specimens dissected. However, since it is a common enough lesion and responds to the same treatment as do those bursae in other parts of the body we may assume that in many persons the bursa does exist. The common disability of the elbow spoken of as "tennis elbow" may be due to an inflammation of the radiohumeral bursa but that is not necessarily so; and the fact that this syndrome known as tennis elbow has had so many names over so many years, makes it difficult for us to outline the various points in diagnosis and in treatment. Synonymous terms are frequently found in medical writings—epicondylitis, epicondylalgia and radiohumeral bursitis. However, they are all grouped in the general diagnosis of tennis elbow, which is not a good term in the sense that it is not at all exact, any more than football knee is an exact diagnosis, because there are many structures about the elbow, just as there are many structures about the knee, that can be injured and give somewhat similar symptoms and physical findings.

Unfortunately, the x-ray is not particularly helpful in most of these instances, because the tissues that are involved, whether they be bursa or tendon or joint capsule or periosteum, are not opaque to x-ray and cast no significant shadow on the film. However, I think that we should emphasize one of the lesions that frequently masquerades under the general caption of tennis elbow, and while it may be a bursitis frequently does not respond to any form of treatment to which a bursa would be expected to respond.

Differential Diagnosis.—Fortunately for the clinician it is not always necessary to make an exact differential diagnosis between these various lesions that occur on the posterolateral surface of the elbow joint, but the various possibilities should be kept in mind, particularly if the lesion fails to respond to the ordinary conservative treatment, which is rest, heat in the form of diathermy, sling immobilization or cast immobilization.

The importance of synovial involvement should be mentioned in a discussion of this type. These lesions can produce an unusual amount of disability. Patients will complain of pain and tenderness (Fig. 79) which will be accentuated by grasping an object or making a fist, particularly with the elbow and wrist extended and the forearm pronated, as illustrated in Fig. 80. Weakness will develop and patients will state that they are dropping objects such as a cup or a glass or a razor; others will have difficulty in performing the finer movements of the hand and forearm, such as buttoning a shirt or tying a tie, knitting, sewing and the like; others will note that their writing is changing due to a shift in the inclination of the pen or to slight necessary alterations in the power of the stroke, and still others will note that there is a grating or grinding

sensation in the region of the elbow, particularly on supination and pronation of the forearm. This can be brought out when the patient is asked to supinate the forearm against the resistance of the hand of the examiner. This maneuver closes the space between the head of the radius and the capitellum of the humerus because of the strong contraction of the brachial radialis muscle. The presence of such crepitation should therefore arouse suspicion that the lesion is in the elbow joint proper rather than in the bursa or in the tendons outside the elbow.

The actual existence of a radiohumeral bursa is questioned by many and therefore radiohumeral bursitis as a cause of this clinical picture may not be as important as is commonly thought. The literature will show that there have been many dissections of the elbow joint made without any actual finding of a definite bursa in this region, and certainly we have never seen in the operating room an unquestionable well-defined

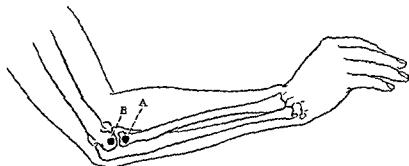


Fig. 79.—A, The common site of pain and tenderness in the true case of radio-

and the injection placed at that point

bursa with endothelial lining and fluid lying between the capsule of the elbow joint over the head of the radius and the overlying extensor tendon of the wrist and fingers. However, it has been described in its inflamed state as a small, pea-sized mass of granular and areolar tissue and fat, lying deep to the conjoined tendon, and for those interested in reading about this subject, Osgood's article is recommended. This article was written about his own elbow which had given him trouble for many many months and which was finally completely relieved by the incision and curetting away of this so-called bursal or granulomatous mass lying between the head of the radius and the tendon structures external to it.

The intra-articular aspects of radiohumeral bursitis or tennis elbow are those that are most frequently neglected in the differential diagnosis, and those are the ones that are least likely to respond to conservative treatment and the most likely to recur after an apparent cure. The synovial lining of the capsule of the elbow in the region of the radio-

humeral joint is redundant, as it must be to accommodate both the flexion and extension and the rotatory movements of this joint. This redundancy may be not only on the lateral aspect of the capsule, but also present in the synovial fringe that invariably covers a portion of the

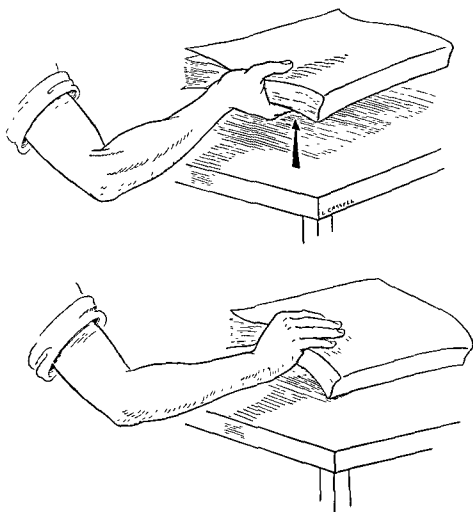


Fig 80.—Test used to make the diagnosis of radiohumeral bursitis, radiohumeral synovitis, or epicondylitis or epicondylalgia involving the origin of the extensor muscles of the forearm in the region of the lateral humeral condyle. In the upper figure the forearm is raised, and tension is placed on the structures about the lateral condyle of the humerus, and it produces the pain and weakness responsible for the inability to perform this particular motion.

quadrates ligament. It can be seen, then, that excessive extension of the elbow, combined with the grasping motion of the hand, leads to an approximation of the head of the radius and the capitellum of the humerus. With the arm and the hand relaxed the head of the radius does not touch the humerus and it is in this space, when closed by the prescribed activity, that pinching of the synovial fringe will occur. The result of repeated

insults to this membrane will of course be hyperemia with subsequent thickening and villous formation as illustrated in figure 81. This mechanism and the result are very similar to the condition that occurs occasionally in internal derangement of the knee; for instance, papilloma may occur following constant repeated injuries to the synovial lining of this joint, and we know that redundancy of the fat pad in the knee can become impinged and produce a definite locking and recurrent hydrops, of the knee.

Another of the intra-articular lesions which may simulate radiohumeral bursitis or tennis elbow is the fraying of the orbicular ligament surrounding the head of the radius, by attrition or by specific manner. The cor-



Fig 81 —The hypertrophic edematous type of synovial membrane that is encountered in those instances in which this particular syndrome is due to pinching of redundant synovial tissue between the head of the radius and the capitellum of the humerus

onary ligament may also be frayed and semi-detached and then caught between the head of the radius and the capitellum in the movement of flexion and extension of this joint. There have been papers suggesting that this condition will clear up without therapy of any kind in about nine months, provided the particular movement which causes the pain is avoided. On the other hand, there are other reports to indicate that such pain may be present for as long a period as twenty years. It is our practice, however, to begin treatment immediately after the diagnosis is made, and conservative measures are tried for a reasonable period, say about four weeks. We have used simple sling immobilization in some, combined with heat in the form of hot packs or diathermy; in others, 1 per cent novocain solution has been injected into the tender area, if

need be a number of times, and if the presence of an inflamed bursa between the conjoined tendon and the capsule over the radial head is suspected, this area is thoroughly needled in a manner similar to that used in treatment of the so-called subdeltoid bursitis. Others will respond to complete immobilization in a light plaster cast extending from the middle



Fig. 82.—X-ray illustrating calcification which sometimes occurs along the course of the origin of pain on the lateral side of the humerus and it is alleged to occur also in the radiohumeral bursa $\frac{1}{2}$ inch or so more distally. However, this calcification as seen here is much more typical than that which occurs in the radiohumeral bursa. It is akin to the calcification that occurs in the tendon substance of the rotator cuff of the shoulder and responds as a rule to the same treatment, such as needling under novocaine anesthesia, which breaks the calcium mass up into fine particles and hastens its ultimate absorption.

third of the arm to the distal flexor crease of the palm, with the elbow in 90 degrees of flexion and the forearm in a neutral position with the wrist moderately dorsiflexed. The majority of patients who have had the diagnosis of radiohumeral bursitis or tears of the conjoined tendon with periosteitis will get well following the use of any or all of these conservative measures. However, those who do not make a complete recovery without recurrence, should then be suspected of having intra-articular involvement such as radiohumeral synovitis, and it is in these patients that surgical treatment is recommended.

Technic of Operation.—The operation consists of an incision about 5 cm. long made in the line usually chosen for the approach to the head of the radius. It is best to do this in a bloodless field, and if the patient can stand the pressure of a blood pressure cuff up to 280 or 300 mm. of mercury, then local anesthesia can be used. If the patient's tolerance to this compression is questionable, then a general anesthetic should be used, because a bloodless field will certainly facilitate the operative procedure. The *conjoined tendon* is incised longitudinally and resected, and the area contiguous to the radiohumeral joint capsule is then inspected thoroughly for the presence of a bursa. The joint capsule is opened and under direct visualization the forearm is flexed, extended, supinated and pronated. It is during this maneuver that the thickened and redundant synovial membrane or the frayed and detached portion of the orbicular ligament comes into view. The offending tissue can be removed without difficulty. It is our thought that failure to open the joint and inspect it for such intra-articular conditions will be the cause of failure to cure any patient with a persistent or recurrent tennis elbow.

THE NEUROLOGICAL ASPECTS OF DEFORMITIES OF THE SPINE

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DEFORMITIES of the spine, particularly scoliosis, are not infrequently associated with disorders of the nervous system. In many instances, however, the underlying or associated neurological disease is not apparent or is overlooked. In still other instances it may be suspected but be unsusceptible of absolute proof. In many of these latter situations it is necessary to apply the unsatisfactory appellation of "idiopathic scoliosis." In order that the relationship existing between these associated abnormalities of the nervous system and of the vertebral column may be understood, various aspects of this complex problem will be reviewed. It is necessary that the general practitioner, the orthopedic surgeon and the neurologist appreciate the many ramifications of the subject in order that they may deal as intelligently as possible with the orthopedic problems, and that they may not overlook any obscure neurological disorders which require independent treatment.

The nature of the association of neurological disease and spinal deformities is multiplex. These relationships may be classified as follows:

1. Independent, associated congenital anomalies
2. Neurological disease secondary to spinal deformity:
 - (a) Tuberculous or other spinal infections
 - (b) Neoplasms of the spine
 - (c) Paraplegia resulting directly from scoliosis
3. Spinal deformity resulting from neurological disease:
 - (a) von Recklinghausen's neurofibromatosis
 - (b) Intraspinial extradural cysts
 - (c) Intraspinial neoplasms
 - (d) Progressive muscular dystrophy
 - (e) Syringomyelia
 - (f) Friedreich's ataxia.
 - (g) Anterior poliomyelitis

SCOLIOSIS AND DISORDERS OF THE NERVOUS SYSTEM AS ASSOCIATED CONGENITAL ABNORMALITIES

It is not uncommon for congenital abnormalities of the nervous system to be associated with somatic malformations which are neither the result of nor the cause of the neurological involvement. Such association exists because some unfavorable influence acting upon the entire organism has arrested or interfered with the normal development of different parts of

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the body at the same time. Thus it is not uncommon to find a meningo-myelocele in the lumbosacral region associated with a forked rib, a horse-shoe kidney, a harelip or a hypospadias (Bucy²). Similar or other malformations of the spinal cord may also be associated with deformities of the spinal column due to hemivertebrae. In the case reported below several hemivertebrae were present, causing a scoliosis in a patient who suffered from a disturbance of the sympathetic innervation in that region.

CASE I—Excessive sweating left side of face and left upper extremity for eight years. Scoliosis secondary to hemivertebrae and spina bifida of lower cervical and upper thoracic spine. Stellate ganglionectomy with cessation of abnormal sweating.

M. S., a 13 year old girl, was admitted to the University of Chicago Clinics on October 20, 1937, because of excessive sweating of the left side of the face and the left upper extremity. At the age of 5½ years she had had three periods of unconsciousness without convulsions. At that time her parents first noted that the left side of her face and her left arm and hand perspired more than did the other parts of her body. This continued, until at the age of 10, after she had recovered from pneumonia, the sweating increased, without any alteration in its distribution. It was also noted that the sweating increased with excitement and that the left hand was always wet and colder than the right one. There was no marked seasonal variation in the sweating but she did not sweat as much when asleep. Because of this excessive perspiration it was almost impossible for her to keep her face clean. Dirt clung to it, and it was streaked in appearance. The excessive sweat quickly soiled her dresses and they soon rotted. Because of this annoying condition she refused to take part in any social activities and was rapidly becoming a recluse.

Examination—The left pupil was constantly larger than the right. The left side of the face and the left axilla, arm and hand all perspired freely. At times the perspiration literally ran down her face and dripped from the left side of her jaw and chin (Fig. 83). The left hand was slightly edematous and cyanotic. The skin temperature in these involved areas was 1 to 1½ degrees (F) cooler than corresponding areas on the other side of the body. Microscopic studies of the capillaries of the skin of the left hand and arm showed no abnormality.

There was a marked scoliosis of the lower cervical and upper thoracic spine with the convexity toward the left (Fig. 84). The left trapezius muscle was considerably smaller than the right, and the left grasp was slightly weaker. There were no alterations in reflexes or in sensation. The blood pressure was 110/82 on the left and 114/92 on the right. The examination was otherwise negative. Blood count was normal.

Roentgenograms—The cervical spine showed a hemivertebra at the lower cervical and upper

thoracic spine. The thoracic spine showed a hemivertebra at the base of the sixth

Operation.—On November 4, 1937, the entire stellate sympathetic ganglion and the second thoracic ganglion were removed from the left side by a posterior approach through the bed of the second rib.

Postoperative Course.—Immediately after operation the area which had previously been the site of severe hyperhidrosis was dry and warm (Fig. 85), and plethysmographic studies were almost identical in the two hands. There was a left Horner's syndrome. The patient has been seen from time to time since, the last occasion being on November 13, 1947, ten years after the operation. The left side of the face and the left upper extremity were still dry. There was moderately excessive perspiration along the lower border of the sympathectomized area, i.e., in the axilla and along a line across the upper chest, both in front and in back.



Fig. 83



Fig. 84

Fig. 83 (Case I).—There is a marked hyperhidrosis of the left side of the face and neck. The scoliosis is also evident.

Fig. 84 (Case I).—The spinous processes of the vertebrae have been marked with ink demonstrating the scoliosis.

The Horner's syndrome was still present but was hardly noticeable on casual observation. The scoliosis was likewise still present but was almost perfectly compensated. The patient has lived a normal, active, happy life ever since the operation and is now married.

Comment.—The patient's chief complaint, localized hyperhidrosis, seems obviously to have been the result of a hyperactivity of the sympathetic nervous system in the cervicothoracic region on the left side. The fact that the skeletal system was distorted by a congenital malformation in this same region can hardly have been mere coincidence. Nor is there any reason to believe either that the deformity of the spine was responsible for the hyperactivity of the nervous system or that the

abnormality of the nervous system had produced this congenital malformation of the spine. Rather, it seems very likely that two malformations occurred in the same region, independent of each other except that



A

B

Fig 65 (Case I) —A, Preoperative. The patient has been painted with an iodine compound and then dusted with starch. The hyperhidrosis of the left side of the face, neck and upper chest and of the left upper extremity have moistened the

The patient has starch and then spire. The former It will be noted, athetic denerva-

both were doubtless the result of the same unknown etiological factor. was the although

the part removed appeared normal microscopically) or of the portions of the spinal cord related to the sympathetic system.

NEUROLOGICAL DISEASE SECONDARY TO SPINAL DISORDERS

Tuberculous Spondylitis.—Neurological disturbances as the result of disease and deformity of the spine are seen most often with tuberculous spondylitis or Pott's disease. Here the spinal deformity is usually a kyphosis, seldom if ever a scoliosis. Furthermore, the dysfunction of the spinal cord which develops in some cases is only rarely the result of the spinal deformity itself. In those exceptional instances in which it is, careful inquiry usually determines that the deformity of the spinal column was suddenly and markedly increased. Such sudden alterations in the spinal deformity usually occur as the result of trauma. In those cases the spinal cord is already drawn fairly tautly across the apex of the vertebral deformity; any sudden increase in the deformity, and thus in the compression of and tension on the spinal cord, is more than the nervous tissue will tolerate, so that paralysis and sensory changes result. It is, however, rather surprising how rarely dysfunction of the spinal cord arises solely from distortion and compression resulting from the deformation of the spine. Usually the kyphosis develops slowly and gradually, and the spinal cord tolerates such distortion very well. It is not uncommon for patients whose spines are bent almost double to have no neurological abnormalities whatever. The following case is illustrative of a large group of similar patients.

CASE II.—Severe deformity of the thoracic spine without any evidence of involvement of the spinal cord. Hospitalized because of left acoustic neurinoma, which was removed successfully.

I. J., a 43 year old woman, was hospitalized on November 4, 1944, complaining of blurring of vision of eighteen months' duration, of headaches for six months, progressive deafness and unsteadiness of gait for five months, and numbness of the left side of the face and tongue for three months. A deformity of the back in the thoracic region had been noted in early infancy and had gradually increased in severity. Use of traction to relieve the deformity had been advised during early childhood, but this treatment was never carried out. There were never any symptoms related to the kyphosis, apart from the deformity.

Examination.—On admission the patient weighed 62 pounds, compared with her usual weight of 69 pounds. She was very short, and there was marked deformity of the chest and thoracic spine resulting from a kyphosis in that region (Fig. S6), with marked prominence of the sternum and the thoracic spine bent into a hairpin curve. There were the neurological changes commonly associated with a tumor in the left cerebellopontine angle: papilledema, nystagmus, diminished left corneal reflex, left facial paralysis, and deafness and diminution in the responses to caloric tests in the left ear. Gait was unsteady, but there were no evidences of involvement of the spinal cord: sensation, muscular strength and reflex activities were all normal in the lower extremities and below the level of the spinal deformity.

Roentgenograms.—X-ray examination of the spine revealed a severe kyphosis of the thoracic spine resulting from extensive destruction of the bodies of many

of the lower thoracic vertebrae (Fig. 86) The thoracic spine and the lumbar spine

Operation—On November 9, 1944, a large multilocular cystic acoustic neuroma was removed. The patient made a satisfactory recovery from the operation and was discharged from the hospital December 8, 1944.



Fig. 86 (Case II)—A, Tuberculous spondylitis. Lateral roentgenogram of the spine demonstrating the very severe kyphosis with marked destruction of the vertebral bodies at the apex of the kyphosis. Note the marked elongation of the lumbar vertebral bodies. B, Artist's sketch to indicate the site and extent of the vertebral deformity.

Comment.—The kyphosis in this patient has been interpreted, both by the clinicians who examined her and by the roentgenologist, as due to a tuberculous infection of the spine. There is of course no positive proof of that etiologic diagnosis, and the possibility cannot be denied that this spinal deformity is due to the disease of the spine by which the disease is discussed. This latter possibility must receive particular attention in this case, in view of the discovery of an acoustic neurinoma in the left cerebello-

of the spinal cord, without any evidence of neurological dysfunction.

Tuberculous Intraspinial Granuloma.—In most cases in which Pott's disease is associated with manifestations of dysfunction of the spinal cord, the neurological disorder is the result of compression of the spinal cord by an extradural tuberculous granuloma arising from and at the level of the infection of the vertebrae. These granulomas encircle and constrict the spinal cord, giving rise to a paraplegia and loss of sensation below the level of the lesion. Because of the encircling nature of these lesions, as well as the fact that vascular changes within the spinal cord commonly result from them, laminectomy and decompression of the lesion and the spinal cord seldom gives beneficial results. Less commonly cold abscesses may appear in association with Pott's disease and compress the spinal cord. Such abscesses not infrequently communicate with even larger collections of pus in the thoracic cavity and the paravertebral tissues. Evacuation of these collections of pus often produces dramatic improvement in the manifestations of the compression of the spinal cord.

Pyogenic Infections.—Pyogenic infections may also be associated with collections of pus or of granulation tissue in the spinal canal, with resulting compression of the spinal cord and paralysis of the legs. However, such disorders usually develop much more rapidly and are not commonly associated with any deformity of the spine at the time of the acute compression of the spinal cord. Later, after some of the vertebrae have been destroyed and the neurological symptoms have either been relieved or become permanent, a deformity of the spinal column may appear.

Neoplasms of the Spine.—It is not uncommon for neoplasms which arise in the vertebral bodies to produce deformities of the spine and to extend into the spinal canal, compressing the spinal cord. Myelomas and giant cell tumors of the spine are the primary neoplasms which do this most commonly; metastatic carcinomas may also do so. The spinal deformity thus produced is usually a kyphosis and the clinical picture develops fairly rapidly, making this situation of little importance either in elucidation of the pathogenesis of scoliosis or in the differentiation of "idiopathic" scoliosis from scoliosis arising as the result of neurological disease.

Paraplegia Resulting Directly from Scoliosis.—As already noted in the discussion of the effects on the spinal cord of the kyphosis resulting from Pott's disease, deformity of the vertebral column of and by itself rarely so affects the spinal cord as to interfere with its function. There are, however, exceptions to this rule. Sachs¹³ reported one of the earliest cases of this type recognized in America. He found the spinal cord and dural sheath to be very much thinned out and to be compressed sharply against the apex of the spinal deformity. Incision of the dura mater and relief of the compression of the cord by the layer of dura mater lying on the convex side resulted in improvement of the patient's condition and return of his ability to walk.

McKenzie¹⁰ reported a similar case in an 18 year old boy, with operation resulting in complete recovery. Recently McKenzie¹¹ has seen and operated on still another patient with this unusual disorder. Viets and

Clifford¹⁴ reported another such case in an 18 year old boy, whose scoliosis was the result of an attack of anterior poliomyelitis at the age of 3; the paraplegia began at the age of 17. Operation resulted in improvement and ability to walk, but some spasticity and reflex alterations still persisted. In a review of the literature they found eighteen cases in which paraplegia was thought to have been a direct result of scoliosis produced by various primary causes. They advised laminectomy and decompression of the spinal cord. Ruhlman and Albert¹² reported seven cases of this kind. They noted that conservative (nonoperative) treatment did not arrest or improve the symptoms. In fact, paraplegia developed in one case while traction was being applied in an effort to correct the scoliosis. They also noted that spinal fusion did not arrest the progress of the neurological disturbance. Laminectomy was performed on five of their patients, with improvement in four. Heyman⁹ reviewed the literature and found twenty-eight cases of this type, 74 per cent of them in males. Conservative treatment resulted in improvement in only 20 per cent of the cases. Ten patients were operated on, with satisfactory recovery in 60 per cent, partial recovery in 30 per cent, and one death. The operation consisted of laminectomy with incision of the dura mater so as to relieve its compression of the spinal cord. Ford⁶ mentions having seen several cases of this type and gives the details of one. This was a 17 year old girl who had a scoliosis, apparently resulting from neurofibromatosis. Paraplegia developed during the two weeks of application of traction to the spine in an effort to correct the scoliosis. A laminectomy produced no improvement. This case and the similar one reported by Ruhlman and Albert serve two purposes. They constitute a warning of the dangers of trying to correct a scoliosis by traction, which many orthopedic surgeons concede is without benefit, and here is definite evidence as to its danger. They also help to explain the development of paraplegia in these patients. Most persons with scoliosis go through life without neurological involvement, despite the severe distortion of the spine and of the spinal cord. Furthermore, most of them have had the spinal deformity for years without any evidence of neurological disorder. It appears that if the scoliosis develops gradually and is not seriously disturbed in a short period of time the spinal cord withstands the deformation without producing symptoms. However, the amount of leeway is doubtless slight. The spinal cord and its enveloping dura mater are drawn tautly over the vertebral prominence. If the relationships are materially and suddenly disturbed, as by traction in these cases or by accidental injury to the spine in some of the others, the spinal cord may not be able to withstand the added strain, its blood supply may also be interfered with, and paralysis and loss of sensation result. It should be reiterated that such cases are very uncommon among the thousands of persons with scoliosis, and that immediate laminectomy and incision of the dura mater give the greatest promise of improvement.

SPINAL DEFORMITY RESULTING FROM NEUROLOGICAL DISEASE

Many different neurological diseases so affect the spinal column or its musculature as to result in deformity, and in many instances the neurological disorder is not readily apparent. Unless one is aware of the possibility and bears it in mind, the fundamental neurological disease is likely to be overlooked in such cases, particularly in scoliosis arising from involvement of the vertebrae by von Recklinghausen's neurofibromatosis.

Scoliosis of the spine also commonly occurs with three well known disorders of the spinal cord. Syringomyelia and Friedreich's ataxia are almost invariably accompanied by this type of spinal deformity; anterior poliomyelitis results in scoliosis only when it causes an asymmetrical weakness of the spinal musculature in a young growing individual. These and other diseases of the spinal cord are discussed in the following pages, with illustrative cases.

Von Recklinghausen's Neurofibromatosis.—Weiss¹⁵ and Brooks and Lehman¹ have pointed out that scoliosis not uncommonly occurs as a complication of this diffuse disorder of the nervous system, but we do not agree with them that scoliosis is almost always present with this disease. Neurofibromatosis is a congenital disorder characterized by pigmented areas and pendulous tumors in the skin, subcutaneous nodules and tumors of the peripheral and sympathetic nervous systems, tumors and malformations of the central nervous system and deformities of the skeletal system. The bony abnormalities are frequently cystic and have been interpreted by some observers as resulting from neurofibromas in the periosteum and within the bone itself. In any event primary destructive lesions may appear in the vertebrae, giving rise to scoliosis. In other cases Brooks and Lehman thought that the scoliosis resulted from inequalities in the length of the legs which had been produced by neurofibromatous interference with growth at the epiphyseal lines of the long bones.

Among the many manifestations of von Recklinghausen's neurofibromatosis are acoustic neurinomas. For that reason, as was noted earlier, the severe kyphosis present in Case II may have been the result of this disease rather than of tuberculosis as was originally suspected.

Intraspinal Extradural Cysts.—In 1937 Cloward and Bucy⁵ described another neurological abnormality which is commonly associated with deformity of the spine—spinal extradural cysts. These are found most commonly in the thoracic region of the spinal canal, although exceptions to this have been seen⁴. They appear to be congenital outpouchings of the arachnoid membrane which penetrate through the spinal dura mater. They usually lie posteriorly to the dural sheath and are filled with cerebrospinal fluid. They communicate with the intradural space by a narrow neck which may be occluded at the time of operation or may still be patent and connect the cyst with the spinal subarachnoid space. They compress the spinal cord and give rise to a slowly developing spastic para-

Clifford¹¹ reported another such case in an 18 year old boy, whose scoliosis was the result of an attack of anterior poliomyelitis at the age of 3; the paraplegia began at the age of 17. Operation resulted in improvement and ability to walk, but some spasticity and reflex alterations still persisted. In a review of the literature they found eighteen cases in which paraplegia was thought to have been a direct result of scoliosis produced by various primary causes. They advised laminectomy and decompression of the spinal cord. Ruhlman and Albert¹² reported seven cases of this kind. They noted that conservative (nonoperative) treatment did not arrest or improve the symptoms. In fact, paraplegia developed in one case while traction was being applied in an effort to correct the scoliosis. They also noted that spinal fusion did not arrest the progress of the neurological disturbance. Laminectomy was performed on five of their patients, with improvement in four. Heyman⁹ reviewed the literature and found twenty-eight cases of this type, 74 per cent of them in males. Conservative treatment resulted in improvement in only 20 per cent of the cases. Ten patients were operated on, with satisfactory recovery in 60 per cent, partial recovery in 30 per cent, and one death. The operation consisted of laminectomy with incision of the dura mater so as to relieve its compression of the spinal cord. Ford⁸ mentions having seen several cases of this type and gives the details of one. This was a 17 year old girl who had a scoliosis, apparently resulting from neurofibromatosis. Paraplegia developed during the two weeks of application of traction to the spine in an effort to correct the scoliosis. A laminectomy produced no improvement. This case and the similar one reported by Ruhlman and Albert serve two purposes. They constitute a warning of the dangers of trying to correct a scoliosis by traction, which many orthopedic surgeons concede is without benefit, and here is definite evidence as to its danger. They also help to explain the development of paraplegia in these patients. Most persons with scoliosis go through life without neurological involvement, despite the severe distortion of the spine and of the spinal cord. Furthermore, most of them have had the spinal deformity for years without any evidence of neurological disorder. It appears that if the scoliosis develops gradually and is not seriously disturbed in a short period of time the spinal cord withstands the deformation without producing symptoms. However, the amount of leeway is doubtless slight. The spinal cord and its enveloping dura mater are drawn tautly over the vertebral prominence. If the relationships are materially and suddenly disturbed, as by traction in these cases or by accidental injury to the spine in some of the others, the spinal cord may not be able to withstand the added strain, its blood supply may also be interfered with, and paralysis and loss of sensation result. It should be reiterated that such cases are very uncommon among the thousands of persons with scoliosis, and that immediate laminectomy and incision of the dura mater give the greatest promise of improvement.

A LeC., a man 31 years old, was hospitalized on May 11, 1948. In 1932 he had several ribs fractured in an automobile accident. About two years later, at the age of 17, he began to have occasional twitching of the muscles of his back, and on inspection his mother noted that his back was crooked. It is not known when this deformity had its onset. About the same time he began to have occasional periods of mild clumsiness of his hands. For two years he was fairly free from

comfort (not a pain) developed in his side, being more marked at night and becoming increasingly annoying. In 1942 an orthopedic surgeon found a scoliosis with the convexity of the curve toward the left and the left shoulder higher than the right. No neurological examination was recorded. On May 20, 1942, fusion was performed in the lower thoracic and upper lumbar region (tenth thoracic through third lumbar vertebrae). Subsequently the wound became infected and drained for four months. Thereafter he was much improved. The discomfort in his side, the fibrillations, and the weakness of his hands and legs are all said to have disappeared. In walking he favored his right leg slightly, but this was attributed to the fact that the tibial graft had been removed from that side. He continued well until about December 1946. At this time he burned his thighs against a radiator without experiencing any pain. His legs gradually grew weaker and by July 1947 he was unable to run. Before long he had to use a cane in walking, and at the time of admission in May 1948 he was barely able to walk with the help of two canes. He also had frequency and urgency of urination and occasional incontinence.

Examination.—The patient was a very slender man who, with the aid of canes, dragged his spastic legs forward in an unsteady, uncertain manner. He was unable to feel pinprick below the eleventh thoracic dermatome, and thermal sensibility was lost below the second lumbar segment. Tactile sensibility was intact. There was marked weakness of both lower extremities. Flexor spasms of the legs occurred spontaneously and on stimulation. The lower abdominal reflexes were absent. The knee jerks were hyperactive. The Babinski sign was easily elicited bilaterally.

On lumbar puncture the spinal fluid was clear and colorless. The initial pressure was 160 mm. of fluid. The pressure rose rapidly on jugular compression to 300 mm. but fell slowly back to the original level. The total protein in the fluid was 78 mg. per 100 cc. There were two small lymphocytes. The Wernicke-Kauffmann test

the blood

Roentgenograms.—The scoliosis of the spine began at about the fifth thoracic vertebra and extended to about the third lumbar vertebra (Fig. 87). There was a dense spinal fusion in the thoracolumbar region, making detailed examination of the spine and of the spinal canal impossible.

Operation.—On May 13, 1948, the upper part of the old incision in the lower thoracic region of the spine was reopened. The upper part of the bone graft and what was judged to be the laminae of the eighth, ninth and tenth thoracic vertebrae were removed. Although no pus was seen, the marrow within the bone graft did not appear healthy. The dura mater was incised longitudinally, exposing a markedly enlarged spinal cord which was yellowish in color. The vessels on the surface seemed compressed and all of the usual surface markings were obliterated.



Fig 87 (Case III) —A composite anteroposterior view of the spine, showing the scoliosis produced by a very slowly growing intramedullary tumor of the spinal cord. Roentgenograms made in 1942 prior to the spinal fusion

Aspiration demonstrated no cystic cavity within the spinal cord. A longitudinal incision was made through the posterior column of the spinal cord just to the left of the midline. About 1 mm. beneath the surface a pinkish-gray gelatinous tumor was exposed, which immediately partially extruded from within the cord. There was no line of demarcation between the tumor and normal nervous tissue. Considerable tumor was removed from within the spinal cord, but by no means all of it, and it did not seem worth while to attempt to expose either the upper or lower limit of the tumor. The dura mater was left open, and the other soft tissues were closed in layers as usual.

Histologic Examination.—The tumor tissue microscopically was revealed to be that of a typical oligodendroglioma. There were no mitotic figures or other evidences of malignancy. The tissue was relatively cellular, and each cell was

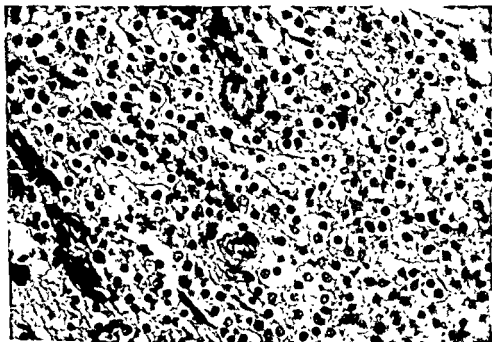


Fig. 88 (Case III).—Microphotograph of the oligodendroglioma of the spinal cord. Each cell is enclosed in a boxlike structure giving the appearance of a cross section of a plant. The walls of the blood vessels are thickened.

enclosed in a definite boxlike framework typical of this type of tumor (Fig. 88). The walls of many of the blood vessels were thickened, and some were practically occluded by this intravascular proliferation.

Postoperative Course.—Since the operation the paraplegia has been complete. The sensory level descended to about the first lumbar dermatome and has remained there. About a week after the operation a rather indolent infection developed in the wound and a staphylococcic meningitis appeared. Presumably this represented a lighting up of the infection which had been present for several months after the operation in 1942; in any event, it subsided promptly with the administration of antibiotics. The patient is now receiving physical rehabilitation.

Comment.—Obviously this is an unusual situation which could only exist with a very slowly growing intraspinal tumor, such as an oligoden-

droglioma, in a young individual. Oligodendrogliomas of the spinal cord are very rare under any circumstance. (This subject will be reviewed and presented in detail in a separate paper with Russell.) It seems probable that scoliosis can develop only when the related spinal musculature is affected in a growing individual. Obviously destruction of bone can give rise to spinal deformity at any age, but such deformities usually take the form of a kyphosis. Furthermore, primary intraspinal neoplasms rarely invade and destroy the vertebrae.

Occasionally another type of intraspinal neoplasm occurring in young people will so affect the vertebrae and the vertebral musculature as to produce another type of vertebral deformity—a lumbar lordosis. Such a case is reported below.

CASE IV—*Girl, at age of 8, had deformity of back, with difficulty in walking, and was treated for Pott's disease. At age 11, pain developed in back and legs, and impairment of sphincters. X-ray pictures revealed enlargement of lumbar spinal canal. Operation, partial removal of ependymoma. Death later from urinary infection.*

H S., a girl of 12, entered the University of Chicago Clinics in January, 1932. In 1925, when she was 5, her family had noted a deformity of her spine. At about the same time she had some difficulty in walking and a weakness of her left ankle. In 1929, a diagnosis of Pott's disease was made and she was treated in a body cast. There was little change in her condition until September, 1931, when she began to complain of pain in her back and legs and of difficulty in controlling the sphincters of her bowel and bladder. Her family thought that the spinal deformity was increasing.

Examination—There was an unusual prominence of the lower thoracic spine which was originally interpreted as a kyphosis. Study of the roentgenograms, however, revealed that the deformity was the result of a lordosis of the lumbar spine which thrust the thoracic spine backward. There was also a prominence of

the pedicles of the second and third lumbar vertebrae (Fig. 90, A). The posterior surfaces of the vertebral bodies in this region were also eroded, making them concave (Fig. 90, B). The laminae and pedicles were very thin.

There was a complete loss of sensation in the third, fourth and fifth sacral dermatomes, with a partial loss from the fifth lumbar to the second sacral. The dorsiflexors of the left foot and toes were completely paralyzed. There was considerable weakness of the ventral flexors of the trunk, causing the patient to

grossly distended, and abdominal compression caused urine to dribble from the urethra.

Lumbar puncture at various interspaces yielded only blood, except for one small piece of yellowish tissue which on microscopic examination had the structure of an ependymoma. The usual examinations of blood and urine were negative.

Operation.—On January 6, 1932, laminectomy was performed from the ninth thoracic to the first sacral vertebra, inclusive. The laminae were very thin and in

places completely eroded through. When the laminae were cut through the ends sprung apart about 1 cm., as if under great tension. Within the dural sheath was a friable, pinkish-gray neoplastic mass which pushed the roots of the cauda equina to either side of the spinal canal. The tumor was removed as completely as possible. Examination of it confirmed the diagnosis of an ependymoma.

Postoperative Course.—Twenty-three x-ray treatments of 275 r each were given to the thoracolumbar spine. The lordosis gradually increased. Pyuria developed in October, 1932, and continued with variable severity thereafter



Fig 89 (Case IV).—Ependymoma in the lumbar spinal canal. The marked lordosis and slight scoliosis are obvious

She had repeated severe epistaxis, a rising blood pressure and severe headaches. In December, 1934, she was again hospitalized because of headaches, dizziness and vomiting, resulting from renal insufficiency, and died on January 4, 1935.

Necropsy.—There was a large intraspinal tumor from the twelfth thoracic vertebra to the first sacral. There was also tumor within the lower part of the spinal cord between the posterior horns. The kidneys were small, with extensive evidence of degeneration and hemorrhage

Comment.—This uncommon type of malformation of the spine is characteristic of an extensive lesion in the lower spinal canal of a child, which weakens the vertebral column by erosion and the paravertebral

muscles by paralysis. The clinical and roentgenologic pictures are not those of a tuberculous spondylitis, and yet the prevalence of that condition as a cause of spinal deformity has been so impressed upon the profession that the erroneous diagnosis was made in this case, as it was in the cases of intraspinal extradural cyst reported by Cloward and Bucy⁴.

Scoliosis of the spine may occasionally develop in a child after successful removal of a spinal cord tumor, as the result of a permanent weakness

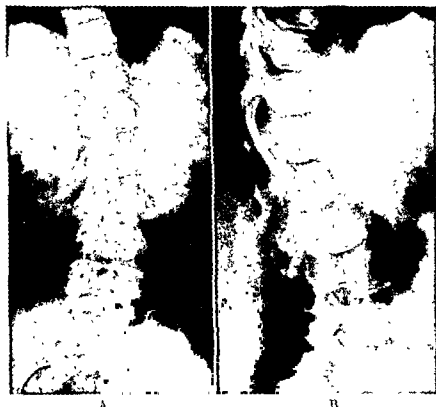


Fig 90 (Case IV) —Ependymoma of the lumbar spinal canal. The canal is markedly enlarged both anteroposteriorly and laterally. The pedicles and laminae are displaced and eroded. The posterior surfaces of the vertebral bodies are eroded giving them a concave appearance.

of the musculature of one side of the spine. The following case, reported originally in 1935 by Bucy and Buchanan⁵ and again by Heimburger and Bucy⁶ in a study of the regeneration of the bony structure of the vertebrae after the removal of pressure, is a typical example of this type.

CASE V.—Male, with weakness of left leg developed at 1 year of age, followed by atrophy and finally paraplegia. Roentgenograms revealed marked dilatation of lumbar spinal canal. Cystic teratoma removed from spinal canal at age 3, followed by complete recovery, except for mild atrophy of left lower extremity and slight scoliosis.

R. B., 2-year old boy, was first admitted to the pediatric department of the University of Chicago Clinics on June 8, 1933. In October, 1932, he had suddenly

become irritable and a stiff neck developed. There was no fever, and the condition gradually subsided over a period of six weeks. However, during this time the left leg became weak and atrophic, although he was still able to walk. A diagnosis of anterior poliomyelitis was made.

On March 19, 1934, he was again admitted to the University of Chicago Clinics. In the interval he had complained of severe pain on movement of his legs and walking had grown progressively more difficult.

Examination.—There were atrophy and weakness of both lower extremities, and he was unable to stand. The left knee jerk was absent, the left ankle and right knee jerks were about normal, the right ankle jerk was hyperactive and sustained clonus could be elicited. There was no demonstrable sensory loss, but the patient was only 3 and not very cooperative.

Roentgenograms.—The spinal canal was grossly dilated from the twelfth thoracic to the third lumbar vertebra. There was marked bony erosion but no scoliosis.

Operation.—On April 10, 1934, laminectomy was performed and a large teratomatous cyst which extended from the twelfth thoracic to the fourth lumbar vertebra was removed from the spinal canal.

Postoperative Course.—His condition steadily improved after operation. In the ensuing 14½ years he has grown into a large, healthy, active boy. He has actively engaged in various school sports. Examination has been performed from time to time; on July 19, 1948, he was a well developed, muscular boy who appeared in excellent health, and had no complaints. The entire left leg was definitely smaller than the right, and there was a definite but not prominent scoliosis of the lower spine. Roentgenograms taken since the operation have disclosed a remarkable recalcification of the vertebrae.³ Films taken on December 8, 1939, five and one half years after operation, showed no scoliosis, but those taken on November 7, 1947 (Fig. 91), and on July 19, 1948, showed a distinct but slight scoliosis of the lumbar spine.

Comment.—Apart from the interest associated with this unusual type of intraspinal neoplasm, the gratifying recovery and the striking regeneration of the eroded and decalcified pedicles and vertebral bodies, this case is of distinct interest in a study of the subject of scoliosis. There is no bony abnormality here to account for the spinal deformity. There is on the other hand a definite asymmetrical muscular weakness and atrophy which is most distinct in the left lower extremity but which in all probability involves the lower spinal musculature as well. This is doubtless the result of some permanent damage to the anterior horn cells of the lumbosacral spinal cord on the left side, or to the motor roots arising there. Not only does this case illustrate the development of scoliosis from an asymmetrical muscular weakness in a young growing individual, as has been stressed elsewhere, but it also illustrates the long period of time required for such a development (over five years in this case), as has been previously noted by other observers in instances where scoliosis has resulted from the paralysis produced by anterior poliomyelitis.

Progressive Muscular Dystrophy.—As the result of weakness of the muscles of the trunk, particularly those of the back which hold the vertebral column erect, progressive muscular dystrophy is commonly asso-

muscles by paralysis. The clinical and roentgenologic pictures are not those of a tuberculous spondylitis, and yet the prevalence of that condition as a cause of spinal deformity has been so impressed upon the profession that the erroneous diagnosis was made in this case, as it was in the cases of intraspinal extradural cyst reported by Cloward and Bucy⁵.

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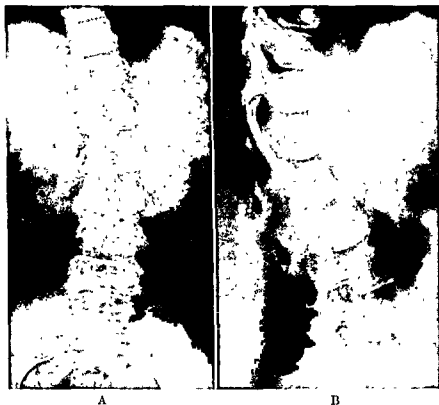


Fig 90 (Case IV) —Ependymoma of the lumbar spinal canal. The canal is markedly enlarged both anteroposteriorly and laterally. The pedicles and laminae are displaced and eroded. The posterior surfaces of the vertebral bodies are eroded giving them a concave appearance.

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horns. Involvement of the pyramidal tracts and of the extrapyramidal tracts which descend with them in the lateral columns of the spinal cord results in a spastic paralysis below the level of the lesion. This disturbance is most evident in the lower extremities and produces a spastic paraplegia. It is doubtful if this spastic paralysis plays much of a role in the development of the scoliosis. The destruction of the anterior gray horns of the spinal cord results in an atrophic, flaccid paralysis of the muscles innervated by the segment of the spinal cord in which the lesion is located. This flaccid paralysis includes the paravertebral musculature and it is likely that it is this which produces the scoliosis. It is interesting that the scoliosis is often the first symptom of which the patient or members of his family are conscious in this gradually progressive disease. The following case represents a typical example of this group.

CASE VI.—Male, noted scoliosis at about 14 years of age. At age 23 years began to limp, and difficulty in walking has steadily increased since. At age 30 numbness and weakness of right hand appeared and the left was involved later. Weakness of external rectus muscle of the left eye, and numbness of the right side of the face also developed.

B. G., a 33 year old man, was hospitalized on June 16, 1948, having been under observation for several years prior to that time. He first became aware of a curvature of his spine when about 14 years old. This deformity had increased so slowly thereafter as to be practically imperceptible. He noted no other disability until he was about 23, when he began to limp on his right leg. This grew progressively worse and three years later he was forced to use a cane; at 30 years of age he first began to use two crutches, assistance he has required ever since. At this time also he noted a numbness and weakness of his right hand which grew steadily worse, and later a similar disability appeared on the left. For several months prior to admission he had had to use a rubber stamp to sign his name. Also at age 30 diplopia developed, but although the muscular weakness persists he has overcome the diplopia. Since the age of 32 he has noted numbness of the right side of his face. There has been no difficulty with the control of his bowel or bladder, and no impairment of sexual function. He continued to work daily at a desk job until the day of his hospitalization.

Examination.—The patient, a rather obese man, had a marked S-shaped thoracolumbar kyphoscoliosis, with the thoracic concavity toward the right and the lumbar concavity toward the left. He was able, with the aid of crutches, to drag his legs in a slow four point gait. He was unable to rise from a prone to a sitting position unaided but was able to maintain a sitting position once it was established. There was complete paralysis of the external rectus muscle of the left eye, and there was a marked nystagmus on looking toward either side. There was diminished pain sensibility over the second and third divisions of the right trigeminal nerve. There were weakness and atrophy of the left half of the tongue and fibrillations bilaterally. Both trapezius muscles were atrophic and weak. No contraction of the intercostal muscles could be detected at any time. The hands were constantly in a flexed position, and there were marked weakness and atrophy of the intrinsic muscles, especially on the right side. The muscles of the arms, except for the right biceps, were practically without strength. There were marked flexor defense reactions in the right leg and practically no voluntary power. All muscles in the left lower extremity functioned but were quite weak.

In the upper extremities the only reflex which could be elicited was a Hoffmann

thoracic dermatomes bilaterally and was diminished over the remainder of the trunk and the lower extremities. Thermal sensibility was diminished below the third cervical dermatome on the right side but was intact elsewhere. There was no loss of tactile sensibility. The usual laboratory examinations of the blood and urine showed no abnormality. Examination of the spinal fluid revealed an initial pressure of 180 mm. of fluid with free dynamics, and a final pressure of 135 mm. of fluid. The spinal fluid total protein was 40 mg. per 100 cc. The Wassermann test was negative and the colloidal gold curve was normal.

Roentgenograms—X-ray examination of the skull and spine revealed no evidence of platybasia, no abnormality of the spinal canal and no evidence of any destruction or malformation of the vertebrae other than an S-shaped scoliosis (Fig. 92).

Diagnosis—The condition seemed to be a typical case of syringomyelia.

Operation—Because Dr. W. A. Gustafson had operated on approximately fifteen patients with syringomyelia, finding a platybasia or an Arnold-Chiari malformation (Bucy and Lichtenstein) or both in a very high percentage of these, and had obtained relief in a considerable number of cases by decompressing the abnormal area, such an operation was proposed to the patient, who readily accepted the idea as his condition was obviously growing rapidly worse, he was almost completely incapacitated and no other form of therapy offered any improvement. (X-ray therapy had been tried without benefit.)

On June 17, 1948, the laminae of the first and second cervical vertebrae and a small piece of skull in the midline of the lower part of the occipital bone, includ-

Postoperative Course.—An indwelling catheter was required for twenty days after the operation, but bladder control was then recovered. For a week after the operation the patient had fever, with nausea and vomiting, and was quite depressed, apparently as the result of blood in the subarachnoid spaces. He is now again up and about on his crutches but, unfortunately, his condition at the time of this report appears to be about the same as it was before the operation.

Comment.—Although the pathologic process revealed at operation in this case was by no means typical of syringomyelia, the clinical picture



Fig. 92 (Case VI).—Syringomyelia. A composite roentgenogram of the entire spinal column. The scoliosis is obvious.

was The latter included early onset (syringomyelia appearing during adolescence), evidence of a flaccid, atrophic paralysis of the upper extremities, spastic paralysis of the legs, and typical sensory changes. In addition, there was definite evidence of a syringobulbia. The involvement of the spinal cord was, as usual, asymmetrical, and it is reasonable to assume that the paralysis of the spinal musculature was likewise asymmetrical. Such an unbalanced paralysis of the spinal musculature in a growing boy resulted here, as it usually does, in a scoliosis.

Friedreich's Ataxia.—This familial and hereditary degenerative disorder of the central nervous system is commonly associated with scoliosis. The degeneration is exceptionally widespread, involving predominantly the long fiber tracts in the posterior half of the spinal cord. Degeneration of the anterior horn cells, although it may occur, is not typical. Nystagmus, dysarthria, facial grimacing and optic atrophy all give evidence of involvement of the central nervous system above the level of the spinal cord. The disease begins early in life, usually between 5 and 15 years of age. The exact neurological deficiency which is responsible for the scoliosis is not clear. There can, however, be little question but that the deformity of the spine is the result of the neurological condition. Since there is no evidence of any primary involvement of the vertebral column.

Anterior Poliomyelitis.—It is a well established fact that scoliosis is a not uncommon sequel to acute anterior poliomyelitis. It would be impossible to determine how frequently scoliosis follows this acute infectious disease of the spinal cord, and no study of any series of cases would give a valid answer to this question. The extent and location of the muscular involvement which occurs with acute anterior poliomyelitis varies too widely from epidemic to epidemic, from year to year and from place to place to make such an all-inclusive study over a long period of time reliable. Even such a study would be meaningless in predicting the outcome in any single epidemic of the disease.

However, certain facts regarding the development of scoliosis following an attack of this disease are well established. The deformity of the spine results from an asymmetrical paralysis of the spinal musculature, producing an unequal pull upon the spine which over years of time results in a spinal curvature, if the subject is a young, growing individual. Forkas⁷, in his study of this condition, demonstrated that the scoliosis does not appear until four or five years after the acute infection, although the muscular paralysis which is responsible for the scoliosis and the changes in the spinal structures which precede it can be demonstrated shortly after the acute episode. It is also significant that the paralysis which follows the spinal infection need not be marked or extensive. In fact there may be little or no paralysis demonstrable in the extremities. The following case, reported through the courtesy of Dr. E. L. Compere, is a typical example of the severe scoliosis which may occur with this condition.

CASE VII.—*Girl, acute anterior poliomyelitis at age 3½ years. Weakness of muscles of trunk and of both lower extremities. Scoliosis first apparent at age 7. Back brace applied at age 8. Scoliosis progressed. Spinal fusion at 16.*

A. C., a 16 year old girl, was hospitalized June 8, 1948. An acute attack of anterior poliomyelitis at the age of 3½ years had left a weakness of all of the muscle groups of the left leg, a right foot drop, and weakness of the musculature of the lower trunk, but no involvement of the upper extremities. When she was 6 years old, operations were performed on both femurs because of malalignment of the legs. When she was 7 years old, her mother first noted a curvature of her



Fig. 93 (Case VII) —Anterior poliomyelitis at the age of 3½ years was responsible for this scoliosis in this 16 year old girl.

spine, which grew progressively worse. When she was 8 years old, a back brace was applied and she was given a brace for the right foot. She has since grown up with the aid of these braces and crutches. However, the scoliosis steadily grew more severe and she was hospitalized for the performance of spinal fusion. Examination of the blood and urine was negative.

Examination—There was an S-shaped spinal curvature with the thoracic portion curved toward the right and the lumbar toward the left. There were also a lordosis and a marked tilting and rotation of the pelvis. The right lower extremity was considerably stronger than the left. The quadriceps extensor muscle was almost normal. All other muscles, although weak, had some power, except

for the anterior tibial group. On the left there was no voluntary control of the muscles of the leg except for internal and external rotation of the foot. The abdominal muscles seemed strong but there was definite weakness of the musculature of the back.

Roentgenograms.—There was marked scoliosis of the entire spine (Fig 93), but no evidence of any bony destruction or of any abnormality of the spinal canal.

Comment.—Discussion of the operations performed on this patient during June and July, 1918, is not pertinent to this report, which is given solely to illustrate the late appearance of scoliosis in a patient who has had anterior poliomyelitis.

DISCUSSION

It is obvious from this presentation that deformities of the spine, notably scoliosis, rarely give rise to any disorder of the spinal cord but frequently occur either in association with or as the direct result of diseases of the nervous system. It may be well, therefore, to summarize some of the characteristics of that etiological relationship.

In order for a neurological disorder to give rise to scoliosis

1. The innervation of the spinal musculature must be affected.
2. The involvement must be asymmetrical

3. The paralysis of the musculature must be either stationary or only slowly progressive. A rapidly progressive neurological lesion or one of only short duration does not provide sufficient opportunity for the scoliosis to develop as the mechanics of the skeleton alone are sufficient to prevent the development of the deformity in a short period.

4. The disorder must occur in a young, growing individual. It would seem that once the spine is fully formed and is no longer growing and changing it cannot be deformed by unequal muscular pull. In this connection it is noteworthy that the scoliosis does not appear until four or five years after the muscular paralysis develops.

Two questions must be answered for the illness to be completely understood, from a neurological standpoint, and for the patient with scoliosis to be treated most intelligently. First, does the patient have some associated or related neurological disease which is in need of independent treatment, apart from the scoliosis? Some of the outstanding examples of this are tumor of the spinal cord, syringomyelia and intra-spinal extradural cyst (in the case of kyphosis). Second, is the patient's orthopedic condition explained by and better understood because of the demonstration of a causative neurological mechanism? If the answer to these questions is in the affirmative, the patient may not feel sufficiently convinced that the scoliosis is the result of a neurological disease, and there is nothing to controvert such a statement.

pathic condition. It is the only fair to state that there is nothing to controvert such a statement.

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COMPRESSION FRACTURES OF THE SPINE COMPLICATED BY INJURY TO THE SPINAL CORD

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IN considering injuries of the spine, one must be concerned whether there is any involvement of the spinal cord, whether the lesion is complete or incomplete, and whether the damage is permanent or temporary. Unfortunately, these questions cannot always be answered in the early stages, and only after a thorough x-ray and neurological examination can any conclusions be reached. Even then one cannot always be certain of the true condition, and further information must be sought. If the type of fracture and the mechanism producing it are well understood, the prognosis and treatment are more readily determined. The majority of fractures of the spine are simple compression fractures of the vertebral body produced by forceful flexion and without any spinal cord involvement. These patients should be treated by some form of hyperextension and immobilization of the spine. However, in a definite group of spine injuries hyperextension should not be used, and, until one knows the true situation of the patient, caution should be the keyword.

PROPER FIRST AID

In some instances, the permanent damage is not caused by the original injury; rather the first aid, transportation and early treatment are at fault. It has been pointed out many times that the patient must not be carried by grasping him beneath his shoulders and knees so that his back may sag, but that he should be rolled over and carried face down on a stretcher. This precept is far too often overlooked. The best method is to roll the patient onto a hard stretcher or board so that he is face down and the spine can be neither flexed nor hyperextended. Thorough x-ray examination should be made as soon as possible, without moving the patient any more than is absolutely necessary. Isolated vertebral fractures may occur at widely separated levels, so complete spine x-rays should be made.

EARLY AND ADEQUATE X-RAY EXAMINATION

Proper analysis of the x-rays is important for both prognosis and treatment. One must bear in mind the fact that, at the time of injury, one vertebra may be temporarily displaced, crushing the cord between the posterior border of the body of the vertebra below and the posterior arch of the vertebra above, and then the displaced vertebra may literally be snapped back to its normal position. In such a case, the x-rays would reveal little abnormality, yet the patient could have an extensive lesion of the cord. This could readily happen in the cervical region, with severe

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tearing of the ligaments of the interarticular and intervertebral joints, thus producing a freely mobile segment. The prognosis in such a lesion of the cervical spine should be guarded. However, complete dislocation with paraplegia can be followed by recovery if the pressure is relieved by reduction of the dislocation, provided, of course, that there is no destruction of the cord.

While the cord is covered by its membranes and surrounded by fluid so that it is well protected, it almost completely fills the neural canal in the upper dorsal spine. Consequently, at this level, the mobility of the spinal cord is greatly diminished, compared with that at the lower dorsal and lumbar levels, and the incidence of severe damage to the cord is thus greater in this area. The prognosis of fractures in the lower dorsal area and particularly in the lumbar area is much better than the prognosis of those at a higher level, because the lumen of the neural canal is greater and the cord is more freely movable in the canal. Fractures of the sacrum are rarely accompanied by nerve root injury. However, with marked displacement of the fragments the distal sacral nerves may be crushed, thus producing incontinence and gluteal anesthesia.

As previously stated, most spine fractures are simple wedging of a vertebral body without any cord symptoms, and are produced by forceful flexion. However, in some instances, paralysis may accompany such a fracture. In many cases, if these fractures are reduced and immobilized, function will return, the paralysis having been caused by so-called "spine contusion." A certain group of comminuted fractures of the vertebral body are also produced by forcible flexion. These cases warrant careful study of the x-rays, as there may be a fragment of the posterior portion of the body extending into the neural canal. In this event hyperextension could be dangerous, as displacement of the fragments could produce cord symptoms or increase the damage to the cord already present. These patients should be immobilized in a plaster jacket, sitting upright with the spine in the neutral position and not hyperextended. This immobilization should be continued for four to six months. Healing is slow in such instances, and frequently a spinal fusion operation is the procedure of choice.

Fracture dislocation of a vertebra constitutes perhaps 20 per cent of vertebral fractures. These patients require special care and attention. Careful study of the x-rays before deciding on treatment is essential. The important point to remember is that the intervertebral joint is dislocated; the fracture itself is of secondary concern. In these cases, forward displacement of one vertebral body on the one below produces one of two effects; fracture of the neural arch, including the articular processes, or complete dislocation of the interarticular joints. Oblique x-rays show more clearly the true nature of such an injury, that is, whether it is a fracture of the articular processes or a dislocation of the interarticular joints. Determination of the true situation is essential prior to the institution of treatment. When the articular processes have been fractured, the displacement can usually be corrected by simple, cautious

hyperextension. When the articular processes are intact and the displacement is due to interarticular dislocation, the problem is more difficult. It is then necessary that the x-rays be studied to determine the relationship of the articular processes to each other. In instances with simple forward displacement, where the ascending articular processes of the lower vertebra are in direct line with the descending articular processes of the vertebra above, simple extension followed by hyperextension will probably reduce the displacement. However, when true alignment of the dislocated articular processes is not perfect, owing to either a lateral shift or rotation, the condition is known as a "*locking of the articular processes.*" This condition, with or without cord symptoms, constitutes an indication for open operation. To try to manipulate these dislocations even by simple traction or hyperextension is hazardous. A closed reduction is a blind procedure in which the vertebrae might easily be displaced in such a manner as to stretch or even tear the cord, thus producing a paraplegia or aggravating any cord symptoms that are already present. With surgical exploration of the area, the articular processes may be exposed; then, with the aid of a small skid and careful flexion of the spine by lowering both ends of the table, the articular processes may be guided into their normal position. This is done cautiously, under direct vision. If such a procedure fails, the ascending articular process of the lower vertebra on the side toward which the upper vertebra is displaced can be excised. This will usually allow reduction.

Fractures of the laminae do occur but are not common. Occasionally a fragment of bone is forced into the spinal canal and causes pressure. This again constitutes an indication for early laminectomy.

NEUROLOGICAL STUDIES

The foregoing paragraphs have dealt largely with the findings on x-ray examination. Proper interpretation of the neurological findings is equally important, and only after review of both the x-ray and the neurological findings can a fairly accurate prognosis be reached and intelligent treatment instituted.

From a neurological standpoint several factors must be considered. It must be remembered that the nerve cells of the spinal cord itself have no power of regeneration. Any destruction of these cells is permanent. On the other hand, the cells of the cauda equina do have the power of regeneration.

Paraplegia may be due to a physiological block produced by contusion of the cord, or by overstretching of the cord due to a bony prominence, without any destruction of nerve cells or nerve fibers. Such a paraplegia may be followed by complete recovery, whether the lesion involves the spinal cord or the cauda equina. However, paraplegia may also be produced by a complete disruption of the nerve fibers, a true anatomic lesion. Such an injury can be followed by recovery only if it occurs in the cauda equina; if the spinal cord proper suffers a complete transection, recovery is impossible. It is therefore obvious that the level of the neuro-

logical lesion is of great importance in determining prognosis. One must bear in mind that the cauda equina begins below the first lumbar nerve

Unfortunately, one is not always able to distinguish at first a paralysis which is due merely to a "physiological block" of the cord from paralysis due to a true destructive lesion of the cord. The clinical pictures shortly after either injury may be identical, with complete flaccid motor paralysis, loss of superficial and deep sensation, loss of the normal reflexes, visceral paralysis and retention of urine. The patient should be treated as if the paralysis were physiologic until it is proved otherwise. In most instances, symptoms of a complete lesion are due to complete anatomic section or crushing of the cord. However, there may be an incomplete anatomic lesion and a physiologic block of the remaining nerve fibers. Therefore, at first, it is sometimes impossible to be certain if the lesion is complete or incomplete, physiologic or anatomic. Only by careful examination and observation of the patient at frequent intervals can one determine with any degree of accuracy the true answer to the problem. Sometimes evidence of an incomplete lesion may be detected by producing forceful flexion and compression of one of the patient's toes in a way that normally would be very painful. If the patient recognizes some sensation during this procedure, the lesion of the cord is incomplete. Recovery in incomplete lesions of the cord may take place over a long period of time. In an incomplete lesion of the cauda equina, improvement may continue for as long as two years. If, on the other hand, there is no evidence of deep sensation and the symptoms of a complete lesion of the cord persist for several days, it is almost certain that there is complete anatomic transection of the cord. This is definitely the case if there is no improvement in three weeks.

About a month after a complete transection the reflex function of the cord is established, and one may note the reflex withdrawal of the leg when the sole of the foot is stimulated. Eventually the flaccid paralysis develops into a typical spastic paralysis.

REDUCTION OF THE FRACTURE

After a careful study of multiple x-rays and a thorough neurological examination, the method of treatment may be arrived at. The present day trend is definitely conservative. Some authors believe that laminectomy has no place in the treatment of these injuries and that it is to be condemned because it removes much supportive bone which is of value to the patient's recovery. I believe that after the type of fracture or fracture dislocation, as the case may be, is carefully determined reduction should be carried out as soon as is reasonably possible. The method of reduction depends on the type of lesion that is present, as was mentioned earlier.

POSTREDUCTION MEASURES

Once reduction has been accomplished, a *Queckenstedt test* should be performed to disclose any blockage of the spinal canal. If there is no

evidence of a block, then the patient should be immobilized by one of the accepted methods, preferably by a plaster cast. It must be pointed out that the only thing to be gained by *laminectomy* is the removal of pressure. If there is no evidence of a block by the Queckenstedt test, laminectomy is of no avail. Certain admonitions in regard to interpretation of the Queckenstedt test may be helpful. If the patient should strain or cough during the procedure, there would be an increase in the intra-abdominal or intrathoracic pressure, causing congestion in the cord below the block and increasing intraspinal pressure. This could happen even in the presence of a complete block of the subarachnoid space, thus giving one a false interpretation of the test. Of course, if there is evidence of a block, either partial or complete laminectomy is indicated. It is thought that laminectomy is also indicated in the following instances: (1) when there is an incomplete lesion of the cord and there is no improvement after two or three days; (2) when improvement occurs for a period after closed reduction and then ceases; (3) when, by x-ray, bone can be seen to be causing pressure on the cord; and (4) when delayed cord compression occurs owing to either hemorrhage or progressive edema.

The question of *proper immobilization* after reduction has been carried out is important. Patients with a loss of sensation are prone to develop pressure sores very readily. The presence of infected decubitus ulcers is a serious complication which may lead to a fatal outcome. For this reason, it is thought that a well made bivalved plaster cast is by far the best method of immobilization, making it possible to turn the patient frequently, and permitting removal of half of the cast so that the skin can be given proper care.

Another great problem presented by the paralyzed patient is the *proper care of the bladder*. When a urologist is available, he should be called on for help. Either frequent catheterization or the use of an indwelling catheter is likely to lead to an infection sooner or later. For this reason suprapubic cystotomy should be strongly considered in the patient with a permanent paralysis or in one with a prolonged convalescence.

SUMMARY

Seven important factors in the diagnosis and treatment of compression fractures of the spine are:

1. Proper first aid, with care to prevent occurrence of both flexion and hyperextension of the spine.
2. Early and adequate x-ray examinations.
3. Thorough neurological studies at the earliest possible time, and repetition of such examinations frequently if paralysis exists.
4. Proper reduction of the fracture, depending on the injury present.
5. A Queckenstedt test to determine the presence of a block of the spinal canal.
6. Laminectomy only when there is evidence of pressure on the spinal cord.
7. Proper care of the skin and bladder to prevent infection.

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COMPRESSION FRACTURES OF THE DORSAL AND LUMBAR SPINE IN ELDERLY PEOPLE

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A FEW years ago a group of surgeons in Milwaukee, Wisconsin, made an attempt to convey the idea to the general profession that "fractures in children are different." It is the purpose of this paper to emphasize the idea that the treatment of compression fractures of the spine in the aged is different from the method commonly taught—which method is, in fact, applicable to younger individuals. Not only does the treatment differ, but the pathology and etiology are not the same as in younger groups.

The authors wish to emphasize a physiological or functional, rather than an anatomical, approach to this problem.

Compression fractures of the spine are seldom seen in children below the age of 10, and in this series of eighty-four cases seen in our service at the Evanston Hospital in the years 1944 to 1947 inclusive, compression fractures of the spine were found in only four patients below that age and in only nine below the age of 20. It is, then, a fracture of adulthood and of the elderly.

MANAGEMENT IN YOUNG ADULTS AND EARLY MIDDLE LIFE

If the fracture occurs in young adults or even in early middle life, complete correction of the compression of the vertebral body is to be arduously sought after and maintained. The younger the patient, the greater should be this effort, because the younger individual has a quicker and more nearly complete recovery from the bad effects of treatment.

Reduction and Application of Plaster.—The reduction is best accomplished under general anesthesia or under a high degree of analgesia produced by the use of morphine and scopolamine. Of the several methods of reduction that have been advocated we prefer using Goldthwaite irons on the fracture table, or the jack and flexible blade on which the patient rests face up, rather than suspending the patient face down between tables on a canvas sling or from the feet. The reason for this is that we believe we can apply a better fitting cast in a supine position. It is easier to mold the plaster about the crest and spine of the ilium, about the breasts and over the manubrium and pubis with the patient supine than prone. The cast must be well molded in order to be tolerable. The position of hyperextension is in itself uncomfortable, and if to this is added the burden of a poorly fitting cast, the situation may become unbearable to the patient. Sponge rubber, sheet wadding, felt, or other padding beneath the plaster does not relieve one of the necessity of molding. In fact,

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it seems that the more padding used the more difficult it becomes to fashion a comfortable and well-fitted cast. The same problem arises in putting casts on fat people. The cast cannot grasp securely the bony framework; it slips up and down over the bony prominences and is much more apt to be uncomfortable.

In younger individuals the reduction and application of plaster is carried out within a few hours after the injury, if possible. A partial paralytic ileus occurs quite frequently following serious injuries of the spine, whether due to accidental trauma or to the trauma of such surgery as a spinal fusion. This complication causes abdominal distention due to gas collection within the gut, considerable abdominal distress, decreased air exchange, and may be associated with difficulty in emptying the bladder as well. It usually becomes manifest a day or two after the injury. If the reduction can be accomplished early and the patient got up and out of bed, the frequency, severity and duration of this complication is probably decreased. If the condition is present at the time of examination, one should wait until it has cleared up before doing the reduction.

Postreduction Aids to Functional Restoration.—Following reduction and the immobilization of the fracture in plaster the patient is encouraged to get out of bed and to increase his activities as rapidly as possible. He is instructed in deep-breathing as well as in leg, arm and back exercises by the physiotherapist. He will usually be able to leave the hospital within two or three weeks and will return to active work in an additional two or three weeks.

Braces.—The original cast may be removed within three to five months and substituted by either a Lenox Baker brace or high spring cage (Magnuson) brace which is used for an additional three to five months. The brace may be removed for bathing and at night for sleeping. A firm, flat bed is recommended. Postural exercises are begun as soon as the cast is removed with the specific purpose of decreasing the lumbar lordosis. The position within the cast and in the brace is one of exaggerated "sway-back," and strenuous effort is put forth to overcome this postural deformity. If the deformity is uncorrected, it becomes more fixed with the passage of time, probably as a real contracture of the muscles and ligaments of the spine, and is itself a common cause of backache. The Lenox Baker brace is very efficient in producing a hyperextension of the spine. It is so effective, in fact, that in cases of minimal compression fractures we have occasionally used it alone without a preceding plaster cast.

Because the brace is so effective, its prolonged use following removal of the cast has the same effect on fixation of the postural deformity of increased lordosis as does the cast. We have found this deformity to be so difficult to correct that we recently have begun to use the high spring cage brace (Fig. 94) as described by Magnuson. This brace can be made so that the lower half applies three-point pressure—that is, over the buttocks, the lower dorsal spine, and over the abdomen—so that there is a tendency to correct the lordosis. This in turn tends to cause correction of the secondary kyphosis in the dorsal area by active muscular effort.

on the part of the patient in standing erect. At the same time the ventral uprights which end in flat knobs just below the clavicles prevent flexion of the spine with increase of weight on the incompletely healed vertebral body.

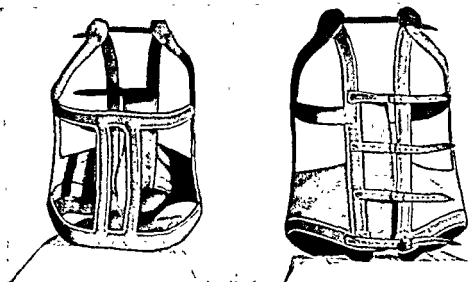


Fig 94—The high spring cage brace.

Measures to Overcome Postural Deformities.—To overcome the postural deformities brought on by the treatment of the fracture we have favored the following program: The patient is asked to use a hard, flat bed so that gravity may aid in straightening the spine. He is to have short rest periods during the day. We feel that two or three rests of approximately twenty minutes each, at intervals of three or four hours, do far more to prevent fatigue than does a single much longer period of rest. Since sitting down is not rest for the spine, the patient is to assume a horizontal position, but whether supine or prone makes no difference. He is instructed in the "pelvic roll" exercise to strengthen the abdominal and stretch the gluteal and sacrospinalis muscles (Fig. 95). Bicycling from a supine position on the floor is done for the same reason. In doing this exercise the patient is cautioned against rocking up on the shoulders. He is instructed to elevate the pelvis only about 1 inch and is to keep the legs pushing straight up from the hip joints as high as possible (Fig. 96). To do this properly requires a great deal of strength in the abdominal muscles and the relaxation and normal length of the low back and hamstring groups. The patient is instructed also to use a small weight on the head at times in order to give himself the "feel" of carrying himself properly.

With the possible exception of a somewhat greater than usual emphasis on postural exercises following the removal of the corrective cast, we believe this treatment corresponds quite closely to "accepted" and "standard" treatment and would differ little from that advocated in most textbooks.

Results.—In spite of attempting to attain and to maintain reduction in this way, however, we found that almost all of our cases showed some degree of residual compression at the end of the healing period. In a few cases we found the same degree of compression as in the original post-fracture roentgenograms. This was a rather rare finding, but equally rare were those cases which showed complete correction of the deformity at



Fig. 95 —Pelvic roll exercise to strengthen abdominal muscles and stretch posterior muscles

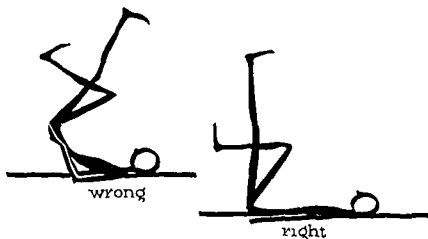


Fig. 96.—Bicycling exercise

the end of the period of healing. The great majority terminated treatment with approximately one half the amount of compression present on the original film.

Judged on a purely anatomical basis, we considered that our results were far from good. Judged from a functional point of view, however, our conclusions were the reverse. Function, as contrasted with restoration of anatomy, was good. Nearly all patients were able to do the same kind of work as they had done before the injury, and for as long a time with no more symptoms of fatigue or back pain or radiated pain.

It may be possible to correlate the amount of symptoms with injury to the intervertebral disk, as manifested in the roentgenogram by narrowing of the intervertebral joint space, sclerosis of the contiguous joint surfaces, and osteophytic lipping and spur formation. It may be possible also to correlate the amount of symptoms with posture. Patients with good posture and without evidence of serious intervertebral disk injury and degeneration tend to have good function without symptoms in spite of moderate compression (amounting to one third the height of the vertebra or less).

Patients with poor posture, manifested by an increase in the lumbar lordosis and dorsal kyphosis, a flat chest, the shoulder girdle carried posterior to the pelvic girdle, the head thrust forward, or with serious degenerative disk change, tend to develop symptoms referable to the back, whether or not there is wedging of the body of the vertebra. Hence the emphasis on postural training.

It is not an unusual experience to find a patient with an old, healed, compression fracture of the spine who denies any unusual "back trouble" and who has not known that he had a "broken back." Careful questioning may bring out that this fracture probably resulted from a severe injury years previously.

It is questionable whether fixation in the hyperextension position is of any value in recovery from the injury of the intervertebral disk or in the prevention of degeneration in the disk initiated by the injury. The position is certainly not conducive to good posture, the other element in the production of symptoms.

It is to be noted that almost all of these injuries were nonindustrial and therefore the question of compensation for maintenance of disability seldom became a factor.

MANAGEMENT IN THE MIDDLE AGED AND ELDERLY

The mechanism of injury in the middle aged and elderly is different. In younger individuals, automobile and motorcycle accidents, diving and tobogganning injuries, and falls from trees accounted for many injuries. At a more cautious and sedate age, falls around the home from chairs or low kitchen stepladders, and falls on icy walks or wet or waxed floors were more frequently responsible. Two patients suffered compression fractures as the result of electric shock therapy. Two individuals suffered compression fracture when they sustained "shock" from a loose electrical connection in the home. The muscular contraction is apparently so strong that fracture may be produced, not only of the spine but other bones as well. This is no longer so apt to occur because curare is more generally used prior to the use of shock treatments. Curare blocks the stimulus at the myoneural junction so that this particular danger is no longer a factor. Senile osteoporosis is frequently associated with compression fracture of the vertebral bodies beginning at the climacteric. This decalcification of the spine is associated in some way with the cessation of the production

of sex hormones. It is frequently seen in females but does occur in males. The menopause occurs in the late forties and early fifties whereas the male climacteric occurs much later. This discrepancy in age undoubtedly accounts for the discrepancy in frequency of osteoporosis on the sexes.

The relatively decalcified spine of senile osteoporosis is structurally weak, and frequently such minor traumas as lifting a weight, sitting down suddenly, going over a bump in the road in an automobile at too rapid a rate, or such sudden muscular contraction as sneezing, have produced compression of the vertebral bodies.

In many instances these fractures involve the bodies of the mid-dorsal vertebrae. Although not so stated in texts, it has been our experience that fractures in this area are much more difficult to reduce than the

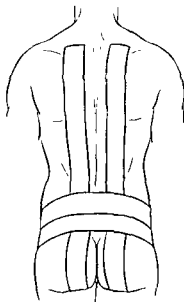


Fig. 97 —Back strapping

more frequent fracture of the bodies about the dorsolumbar junction. It is also much more difficult to maintain reduction. In younger individuals we have used a body cast which included the base of the skull and the jaw for fracture of the body of the ninth dorsal vertebra, or those vertebrae above it, as the most effective way of retaining reduction. This procedure is totally intolerable to the group of patients under discussion and, in addition, unnecessary, and may endanger the very life of the patient. These considerations have led us to adopt an entirely different concept of treatment for these fractures in the elderly and middle aged.

Often we accept the deformity that is present and make no attempt to correct it. This is particularly true in the patient with senile osteoporosis who presents herself one or two weeks after her injury because she does not seem to recover from her "lame back." Frequently a few weeks of strapping (Fig. 97) followed by the use of a very well-boned corset will

effect complete freedom from symptoms. The corset should be front-lace, it should extend well up the back to just below the scapulae, and there should be a strong brassiere which comes down over the top of the corset in the back. Most women object to corsets with belts and buckles to draw them in, because they fear that these appliances may be obvious through their clothing. If a corset is properly made and fitted, such straps and buckles do seem to be unnecessary. Heavy braces, such as the Taylor brace, in our experience, have been left quietly in some closet at home so frequently, that it has seemed better to recommend a less rigid support that will be worn; and the more so since we doubt both the efficacy and the necessity of the Taylor brace.

In most cases in this age group it will be necessary to hospitalize the patient because of the severe pain and disability attendant upon the injury and the need for uninterrupted rest to the injured part. The patient

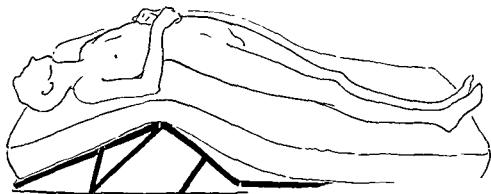


Fig. 98—Passive hyperextension of the spine.

is placed in a "two crank" hospital bed which has an adjustment to elevate the knees, as well as one to elevate the back rest. His head is placed to the foot of the bed and his feet to the head, so that the injured vertebra is just above the highest point when the knee rest is elevated (Fig. 98). A hinged sectional plywood board is placed between the mattress and springs.

For a few days some analgesic such as demerol or codeine and aspirin, in relatively small doses, and sedatives may be indicated. Pain produced by spasm of the back muscles is usually in part relieved by hot compresses. We believe that the most effective method of application of these compresses is that advocated by Sister Kenny. Occasionally curare for two or three days is of value in relief of painful muscle spasm. Of course, the drug must be used with some caution in elderly people.

The patient is strongly impressed with the danger of lying completely passive; he is instructed to use deep-breathing exercises every waking hour, and to move arms and legs at intervals. He is taught to contract one set of muscles against its opponents, after the manner of the professional "strong men" and "muscle builders." At first he is turned on his side and abdomen three or four times a day by the nurses. Soon he becomes able to turn without aid and without pain. Pain is the warning

signal. He is told that what he can do without pain, at the time of activity, or later, is permissible.

He is given a diet high in proteins and vitamins, and supplementary vitamins are used. Elderly patients not infrequently have difficulty obtaining a bowel movement under the circumstances, so a mild laxative is used from the first. Vegetable oil retention enemas followed in the morning by tapwater enemas may be necessary. Fecal impaction may be expected if active measures are not used.

The spine is hyperextended for twenty to thirty minutes three times a day by elevating the knee rest while the patient is in the supine position with the injured vertebra just above the break in the bed (Fig 98). The degree of extension is gradually increased from day to day, as is the length of time spent in this position. One must secure the complete co-operation of the patient, and he must be properly motivated by an understanding of what one desires to accomplish by this procedure, for it is somewhat tiresome and painful.



Fig 99.—Active hyperextension exercise

From the first, the physiotherapist sees the patient at least once, and preferably twice, daily. At first she merely uses heat to the back and massage to relax and rest the muscles and trains the patient in deep-breathing exercises and in muscle setting. Within a day or two she begins cautious active extension exercises with the patient in bed, prone (Fig. 99). Later the patient may be transferred to the regular table by cart and much more strenuous active exercises begun. Pain or spasm or fatigue is always the limiting factor as to rapidity of progress. Usually within a few days, sometimes after two to three weeks, the back is strapped, not for support but to act as a check-rein, a reminder that forward flexion of the spine is forbidden, and the patient starts to sit in a hard, high chair, to stand, and to walk. He is then given a high spring cage brace or a corset and is usually ready for discharge from the hospital some two or three weeks after admission. The postural exercises continue at home if necessary under the direct supervision of a physiotherapist. The exercises are to be persisted in at least during the period of healing, or not less than six months.

CONCLUSION

It is understood that there is nothing new in the method of treatment advocated. However, it is believed that good treatment is based upon

fine differentiation of cases; that the treatment of compression fractures of the spine in the middle-aged and the elderly should be different from that used for the same lesion in the younger ages. Emphasis is placed upon restoration of normal function of the back as a whole, rather than upon restoration of normal anatomy.

ILLUSTRATIVE CASES

The following cases are illustrative of types seen in this series.

CASE I.—A 68 year old, obese man entered the hospital on September 2, 1946, with a chief complaint of injury to his back. The day previously he had fallen a distance of about 8 feet from a ladder in the yard of his home, catching his weight on his feet and then falling to the sidewalk. He had immediate pain in his back and for a short time felt faint and sick to his stomach, although he did not vomit. Following the injury any motion of the back was very painful.

On examination his blood pressure was found to be 150 over 90; his pulse 76; his weight was 200 pounds; his height was 5 feet 9½ inches. There was a marked kyphosis in the dorsal region with secondary compensatory lumbar lordosis; marked muscle spasm of the sacrospinalis on either side and exquisite tenderness on pressure over the fifth and sixth thoracic spines. There was no actual gibbus. A soft, faint, blowing systolic murmur was heard over the apex and the aortic area, and marked rales were heard over the anterior chest, especially at the lung bases. Deep reflexes were physiological and equal in both upper and lower extremities, and there was no sensory change.

X-ray of the dorsal spine showed a rather marked compression fracture of the sixth dorsal vertebra. The vertical dimension of the body of the vertebra was reduced to 12 mm. as compared to 22 mm. for the fifth dorsal vertebra. There was hypertrophic changes on the margins of several of the dorsal and lumbar vertebrae, and calcium was deposited in several of the intervetebral disks. Repeated electrocardiographic tracings were obtained which were compatible with the posterior coronary occlusion. Routine laboratory examination, including serology, complete blood count, urinalysis and biochemistry was normal except for a moderate elevation in the non-protein nitrogen and an elevation of the sedimentation rate by the Westergren method to 18/85.

The patient was placed with his head to the foot of the hospital bed so that with the knee rest up the back could be hyperextended. He was placed on a bland diet and given a mild cathartic. Hot compresses were applied to the back from the neck to below the hips for one hour three times a day. Deep breathing exercises were prescribed and continued.

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After about two weeks he was given postural training exercises and hyperextension exercises in an upright position. He left the hospital after a stay of just short of four weeks, wearing a corset, and was instructed to continue his exercises at home.

This patient was re-examined in August of this year at the age of 71. He stated that he had no discomfort during ordinary activities. He had no pain at night and no particular stiffness in the morning. He did complain of back pain in his back after doing excessive exercise such as cutting the grass or walking more than a mile, but the tired aching tended to disappear after a short rest. There was

no radiation of pain to the legs or the buttocks. His back ordinarily does not feel tired or weak, and he wears no support. He believes that he has no disability as far as his back is concerned. Back motions were found to be painless in all directions, and motions were good considering his age. There was a marked thoracic kyphosis in the upper dorsal region of the senile type. There was no particular tenderness on palpation or heavy percussion of the spine. Hip and leg motions were normal. Straight leg raising was possible to 80 degrees. Lasègue's and Patrick tests were negative. Reflexes in the lower extremities were physiological and equal, and there was no sensory change.

CASE II—This 57 year old white woman fell down the stairs in the dark at home on August 4, 1945. She says that she fell head over heels and came to rest on her shoulders. She had severe pain in the back but was able to get into bed with the help of her husband. She was hospitalized on August 7, 1945. Back motions were found to be very limited because of pain. Muscle spasm was present to a marked degree. There was marked tenderness to palpation and percussion over the dorsolumbar region. The patient had felt nauseated shortly after her fall. Reflexes in the upper and lower extremities were normal, and there was no sensory disturbance. General physical examination revealed no pertinent abnormality, and routine laboratory studies were within normal limits. X-ray examination of the spine revealed a compression fracture of the body of the eleventh dorsal vertebra, amounting to about one half the height of the vertebra.

Treatment in the hospital consisted of reversing the patient's position in the

a hypostatic pneumonia, the use of metaniacil to prevent fecal impaction; and physiotherapy, starting first with heat and massage to the back, later adding prone hyperextension of the spine and then standing postural exercises. The patient was fitted with a high, well-boned corset and was discharged from the hospital after three weeks. She was to continue the exercises at home under the supervision of a physiotherapist.

This patient was also re-examined in August of 1948, three years after her injury. At this time she states that she has no back pain, weakness or instability. She does all of her own housework without difficulty and does her own gardening.

or palpation of the spine, except slight tenderness over the lumbosacral joint.

CASE III.—A 60 year old female was first seen in June of 1945 because of pain in the back. She stated that six weeks previously she had attempted to raise a window. The window was stuck, and she jerked hard on it. She had immediate

She was told that she had a muscular strain and was given diathermy treatments several times a week without benefit.

Examination revealed a thin asthenic individual who indicated the lower dorsal region on either side of the spine as the site of pain. Her general posture was poor, there being a marked increase in the dorsal kyphosis and in the lumbar lordosis. There was no lateral curvature and no list. There was marked muscle spasm in either sacrospinalis group. There was marked tenderness on palpation of the lower dorsal spine, and pressure here caused pain to radiate into the abdomen on either side. Back motions were almost completely abolished. The patient moved with extreme caution because of pain. X-rays were obtained which showed a moderate compression of the body of the tenth dorsal vertebra with marked generalized osteoporosis of the spine and pelvis. It was felt that she had a marked senile osteoporosis with old compression fracture of the body of the tenth dorsal vertebra, and marked poor posture. She was placed in the hospital and bilateral Russell traction applied with the patient in semi-Fowler position. Compresses were used for relief of muscle spasm and pain; traction was maintained until the acute stage had passed in about ten days, and physiotherapy consisting of heat massage and postural exercises was started. She was discharged from the hospital after three and a half weeks wearing a good corset. The disability and pain associated with the back injury gradually cleared up and she was able to lead a normal life.

Two and a half years later she had another episode of acute back pain after lifting a weight from the floor. X-rays revealed again a marked senile osteoporosis. She was given estrogen and androgen medication; her back was strapped on several occasions; and rest periods were prescribed throughout the day. She gradually improved. She refused to continue hormone treatments because of the expense after only about three months of treatment.

This patient was re-examined in August of 1948. She wears a well-boned corset and says that if she tries to get along without it her back tires easily. She is able to do her own housework and considers that she has full activity, although she admits that a one or two hour rest after lunch makes her feet better. Examination at this time revealed the marked thoracic kyphosis and increased lumbar lordosis. Back motions were not especially restricted; hip motions were normal; straight leg raising was possible to 90 degrees on either side; and Lasègue's test was negative. There was no particular tenderness over the spine to palpation or percussion. Deep reflexes were active and equal, and there was no sensory disturbance.

TREATMENT OF SCOLIOSIS

FERDINAND SEIDLER, M.D.*

IN discussing the treatment of scoliosis we must deal separately with the different types, *i.e.*, (1) congenital, (2) idiopathic, (3) rachitic, (4) paralytic and (5) ischiatic scoliosis, and (6) scoliosis due to chest disease and rib resections.

CONGENITAL SCOLIOSIS

Congenital scoliosis is characterized by a sharp rigid curve involving only a small part of the spine, mostly the upper thoracic or cervical region. There we see vertebrae fused together, fused ribs, hemivertebrae, spina bifida and so on. If the hemivertebrae are symmetrically distributed, the weight-bearing alignment of the spine is not disturbed; if not, a sharp curve may be found. But as the area involved is, as a rule, not large, the deformity is easily compensated. There are reports in the literature of excision of hemivertebrae. Such heroic treatment will seldom be warranted.

IDIOPATHIC SCOLIOSIS

Idiopathic scoliosis remains an unsolved problem. I shall not discuss all the different theories of its etiology. One needs a working theory, however, and I should like to present my own conception of this problem. The existence of a physiologic scoliosis is now generally accepted. It is in 80 per cent of the cases a right convex dorsal, left lumbar scoliosis. The asymmetric distribution of our inner organs and our uneven gait seem to be the factors at work. It is not seen before the age of 6 and increases with advancing age. Structural changes are seen in the aged, according to Farkas. We see wedge-shaped vertebrae at the apex of the curve, rhombic between the wedge-shaped and the neutral ones. The transverse processes are in the frontal plane on the concave side, and in the sagittal plane on the convex side. There is a change in the direction and shape of the articular processes. The axes of the body and of the neural arches form an obtuse angle open toward the concave side. The foramen spinale is egg-shaped instead of round.

Changes identical with those of physiologic scoliosis are found in the idiopathic type, but in the latter they are much more pronounced and aggravated. There is an inherent deforming factor in every spine. Whether we shall stay straight to ripe old age or develop a kyphosis or scoliosis depends on the equilibrium between our endeavor to attain and maintain the erect posture and this deforming factor. If the deforming factor wins the upper hand in the growing period, then a severe deformity will result. While a fully developed normal bone will slowly and in

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limited extent change its shape under mechanical stress and strain, the growing bone can be easily molded, the epiphyseal plate will change its direction of growth under unequal pressure

What is the reason that some children lose the fight against this deforming factor? Heredity might be one. Every orthopedic surgeon has histories of a few scoliotic families in his file. Insufficiency of the back is another reason. This, of course, is a vague term. These children are tired, anemic, do not gain weight properly. There is a disproportion between the bony development and their muscular ligamentous system. The result is poor posture. The usual or habitual posture is between the fully relaxed and the erect or military posture. The closer the habitual posture comes to the fully relaxed one, the poorer it is

The influence of school life upon the development of a scoliosis is an open question. Much has been written about the bad influence of sitting for long periods, of improperly built benches, about the distance of the chair from the table, about the difference in height between chair and table. If the table is too low the child has to stoop, if it is too high the child has to pull up his arm and shoulder in writing and curve the spine. These, of course, are aggravating factors but they are not the cause of scoliosis, the child brings the scoliosis to school. But the school cannot be relieved of its responsibility completely. Periodic examination of all children by a competent orthopedic man is essential. The weak back, the poor postures, the scoliotic postures and the real scoliosis should be found. Elevation of one shoe or a slanting seat to counteract the inclination of the pelvis to one side may be enough in many instances. Rest periods and frequent stretching with deep breathing during classes may be prescribed. More time should be given to play and exercises

This brings us to the question of special exercises for the scoliotic. To be frank, I never saw much improvement in the cases I referred from the clinic to the visiting nurses' association. Besides, no exercises are indicated for the real insufficiency of the back. A horse that is on the verge of breaking down does not need the whip, it needs oats and rest. The same holds true for these overworked muscles, which scarcely can keep the body erect. They do not get stronger by being tired out some more.

In cases, Muscles do not atrophy in
erector spinae muscles, can work,
when the constant strain of keeping

the body erect is taken from these muscles, they can be exercised sensibly. Böhler showed in his treatment of fractures of the spine by vigorous exercises in a plaster corset, that the full strength of the back was retained.

More involved becomes the problem of scoliosis with structural changes. We shall consider first the most common type—a left convex lumbar, right dorsal scoliosis. In our opinion the lumbar curve is always the primary one and the dorsal the compensatory. But this is not important. The important question is, which curve is rigid and which is

flexible and how much flexibility is left or are both curves rigid? If we admit the theory that an uneven gait or a lateral inclination of the pelvis is an etiologic factor, then the first symptoms should occur in the lumbar spine. The lumbar spine curves with the convexity to the left. This curve as a rule comprises the whole lumbar spine, the twelfth dorsal being the neutral vertebra. The whole body is now leaning to the right. As our organism tries by all means to keep the head up, with the eyeline horizontal, the dorsal spine has to bend back in opposite direction. When one tries to straighten a young tree that is leaning to one side, one would not tie a rope around the tree close to the ground and pull, as this would take too much strength. One fastens the rope as high up as possible and pulls. When the tree is still flexible it will bend. The same holds true for the spinal column. The part of the muscle attached to the lower part of the dorsal spine cannot straighten it. The portion higher up, working under more favorable mechanical conditions, will accomplish it. And as long as the spine is a flexible rod it will bend. If the upper part bends too much, then the cervical spine has to compensate that by a counter-curve. The dorsal curve has to be kept in this position to maintain the upright posture and rapidly becomes rigid. Furthermore, the dorsal spine with the thoracic cage is more rigid than the lumbar spine and therefore will always be the more rigid curve, which however does not imply that it is the primary one.

Every case of structural scoliosis is a serious problem, but not necessarily a surgical problem. Some cases respond well to conservative treatment. Assuming again that the lumbar curve is the primary one, we try to straighten this curve, trusting that the dorsal curve will take care of itself. Taking again a patient with a left convex lumbar, right dorsal curve, we bend the body to the left side. We apply traction with the Glisson sling and let the patient step to the right, right hand high and left arm horizontal. It is a matter of experience how much correction to give the first time. Even if the lumbar spine could be straightened completely, the dorsal curve would not yield and the child could not straighten out.

We give as much correction as we deem advisable and put on a plaster jacket that fits well around the pelvis and extends as high as the apex of the dorsal curve. This upper edge has to be well padded with felt. We let the patient lie in bed a few days and use traction on the head in the beginning. If proper judgment is exercised the patient will straighten out shortly. The cast is changed periodically and finally replaced by a brace. The treatment takes years, I admit, but little time is spent in the hospital and the children are not handicapped at all. If we get a straight shoulder line, no prominence of either hip and a strong back, we call the result satisfactory, even if a slight, well compensated curve persists.

This method is highly useful and gives some improvement in the case of a high thoracic curve that cannot be treated in a Risser jacket. There are two types of cases, however, which cannot be treated successfully by this method, namely the rigid backs that cannot straighten spontane-

ously and the ones that will correct but for some reason or other will not hold the correction

This brings us to the severe type of structural scoliosis that has to be corrected forcibly. A thorough analysis of each case is important. Good x-ray films which allow exact recordings of the curves and the pelvic tilt test are essential. Should it be the case that the lumbar spine is rigid too—a so-called double primary curve—then the lumbar curve would need forcible correction and fusion also. If this is not done, a prominent hip results and a high heel lift is necessary to secure body balance. This is certainly not a desirable result. Outland suggests the use of a Risser jacket with two hinges and two turnbuckles to correct both curves simultaneously. Fusion of the whole spine with interlocking tibial grafts is done afterwards.

A more desirable procedure might be to obtain as good a compensation as possible by the Steindler derotation method and fuse one curve to prevent progress of the deformity.

The forcible correction may be done in the Risser hinge jacket, probably the most widely used method. A well applied Risser jacket is a work of art. Its application requires some experience and practice and a well trained nursing staff. I would not advise anyone to attempt to apply one after only reading its description or having watched its application once. The proper equipment is also essential.

Le Mesurier uses a hammock. Blount and Schmidt constructed a complicated mechanical appliance. Von Lakum cuts the cast in two places and pulls the middle part straight lateral against the top and bottom parts, getting good correction that way. Thomas in Liverpool puts his patients to bed for eight weeks on a frame with lateral pressure pads. The method with which one is most familiar will probably be the one that is used.

All methods, if successful, secure a certain amount of correction in a comparatively short time. No increase in force or length of time will be of avail. The result of undue force is pressure sores, brachial paralysis, a sore mandibular joint with malocclusion—too high a price for a few more questionable degrees of gain.

Before the cast is stabilized for the operation a derotation of the dorsal spine improves the appearance of the back considerably.

Just a few words about the rotation. The spinal column is a rod with different degrees of flexibility in its posterior and anterior portions. While the neural arches bend sideways readily the vertebral bodies cannot bend in a curve of the same radius. They need a larger radius, consequently they have to move farther away from the midline which brings about the rotary motion. The rotation is firmly linked to the lateral motion. The lateral motion is the wide excursion, the rotation is on a small scale. Any attempt to influence the side motion by a rotary force is mechanically unsound. The Galeazzi derotation machine is ready for the museum. Steindler calls it preposterous to try to derotate the thorax, as the spine has rotated too far toward the ribs already. Hibbs says that

derotation improves the appearance but does not add to the correction of the lateral curve. But patients do not exhibit their x-ray films—they show their backs. They undergo the whole ordeal of this treatment to improve their appearance. Anything that serves that purpose is worth doing.

After the correction is obtained the fusion area is determined. The principle of delineating the fusion area has been well laid down by Ferguson. But I would like to caution against extending the area too far down into the lumbar curve, if there is some rigidity. It is better to lose some correction due to too short a fusion than to risk either a pseudarthrosis or an unsightly high hip which will be a source of trouble in advanced age.

In the fusion operation, it seems accepted by the majority that exposure of the laminae on the convex side is not necessary. Reinforcement of the fusion by bone grafts is desirable, however.

End results vary according to different reports, statistics showing from 40 degrees final correction to as low as 5 degrees. The result depends first on the original correction obtained, secondly on the firmness of the fusion, and last but not least on the area of fusion. We fused the rigid dorsal curve, not the primary lumbar one. There the deforming factor is still at work. The key to the situation is the area where the lumbar curve changes into the counter curve. If motion there is eliminated by extending the fusion far enough down, then the lumbar spine cannot bend without throwing the whole body out of the weight-carrying line. The erector spinae muscle will counteract this with all its force. Its most efficient pull is on the upper end, as stated before. If this upper end is not a flexible rod any more as a result of extending the fusion area up high enough, body balance will be maintained without curvature.

RACHITIC SCOLIOSIS

The rachitic scoliosis follows the pattern of the idiopathic type. The difference is that the deforming force acts here upon a pathologic soft bone in early infancy. Outside influences have a much greater effect on a rachitic spine. The practice by some mothers of carrying infants on one arm where they sit with a slanting pelvis, the upper body curved against the woman's chest, certainly creates a beautiful S curve. Spitzzy stressed the fact that scoliosis was not as frequent in Japan as in Austria although the incidence of rachitis was the same. The explanation is that Japanese mothers carry their babies on the back, not on the arm.

We seldom see a case of idiopathic scoliosis before the age of 6, and few before the second period of rapid growth. The rachitic scoliosis on the other hand is seen in early infancy.

The treatment of choice is the use of a plaster of paris bed coupled with a general antirachitic regimen. If these children will lie twenty-four hours a day in the overcorrected position in a plaster bed or a Bradford frame, remarkable correction can be obtained. The plaster bed is preferable as it gives better immobilization. It is tilted about 45 degrees. The

children lie on the dorsal convexity, with head and pelvis lower. A mild pulling effect is thus exerted on the dorsal curve. More felt pads can be added for more correction and the plaster shell of course is renewed from time to time. The bed is finally replaced by a body cast when the improvement is enough to allow ambulation. By these means severe deformities can be prevented. Old rachitic curvatures are treated like the idiopathic ones, but the results are less favorable since the bony deformities are too pronounced.

Mention should be made of a curve appearing at the age of late rickets, when we see *coxa vara* and Scheuermann's *kyphosis*. We see it in boys who quit school early and start working too hard. The curve is confined to the dorsal region without much lumbar involvement. It is obviously a disturbance in the cartilage plates which are the growing center of the vertebral bodies. Schaefer and Purcell's treatment of idiopathic scoliosis with desiccated thyroid might be indicated in these cases.

PARALYTIC SCOLIOSIS

An entirely different problem is the scoliosis due to poliomyelitis. We know how irregular poliomyelitis is in its distribution. Any muscle or number of muscles may be involved. They may be only slightly weakened, severely damaged, or completely and permanently paralyzed.

When we then consider the number of muscles arranged symmetrically on each side of the spine acting partly synergetic, partly antagonistic to each other, the muscles on the front of the abdomen acting synergetic or antagonistic to each other and to the back muscles, the muscles controlling the position of the pelvis in relation to the spine and the extremities, we can in a measure appreciate the infinite number of combinations and variations of disability that may be possible.

When we deal with a paralyzed leg or paralyzed arm we can analyze the case thoroughly and reach a conclusion of the damage done. We can figure out exactly the deformity that might result and can take precautions accordingly and outline the treatment. Such analysis is impossible in the trunk. The motion is too complex. Most muscles are too deep-seated for electric examination.

Therefore, we should in every case of poliomyelitis be on the alert for spine involvement even if there is no obvious loss of motion. If we find some weakness of the abdominal muscles or any loss of motion in the spine or pelvis, treatment is imperative. Treatment means absolute bed rest on a hard mattress or Bradford frame for many months. But even recumbency will not eliminate unilateral rotary pull. We might see rotation develop in spite of strict recumbency, especially the vicious rotary effect of the oblique abdominal muscles, which is as a rule underestimated. The rotary deformity will lead to lateral bending as soon as weight bearing is started. Good support is essential during the time of recovery to prevent deformities. Fortunately many patients do recover without apparent scoliosis or with only a slight one easily compen-

sated. For the severe type of paralysis with complete loss of stability, fusion is indicated.

It should hardly be necessary to mention that before dealing with the spine a thorough examination of the whole patient is important. We watch the gait, note any inequality in leg length or limp, note the position of the pelvis, forward tilt or lateral obliquity. We have to start at the foundation, see figuratively that the spine rests on level ground. I refer you to Leo Mayer's work for the method of correcting any fixed pelvic obliquity. The spine is fused after correction in the usual way, the same rules as for idiopathic scoliosis apply here.

We have all observed that a well fused ankle will develop a deformity again if a one-sided muscle pull is allowed to persist. The same holds true in scoliosis. Some patients lose almost all correction in spite of solid fusion. Muscle transplantation around the trunk has only a limited field, but some interesting work has been done with fascial implants by Lowman and Colonna. My own experience in this field is too small to permit conclusions. I would like only to stress one point in those cases of paralysis of the sacrospinalis muscle. It is generally accepted that the strong sacrospinalis is on the concave side. There are cases, however, in which the strong sacrospinalis is on the convex side. The patient curves the spine against this muscle to get a more efficient pull, hanging so to say on this muscle and preventing the spine from tilting toward the paralyzed side. This should be considered before an implant is done.

SCOLIOSIS DUE TO RIB RESECTIONS AND EMPYEMA; SCIATIC SCOLIOSIS

Scoliosis due to rib resections and empyema depends on the extent of the previous surgery, the amount of scar formation and the age of the patient. The process is self-limited and usually needs no treatment. Rib resection as a treatment for scoliosis might be mentioned here. Ribs have been resected on both the convex and the concave sides. The results were not encouraging.

Sciatic scoliosis is definitely a position of pain. The convexity is as a rule toward the sound side. Sometimes we see the convexity toward the affected side and some patients change, present one day aright, the next a left convex lumbar scoliosis with the sciatic pain constant in the same leg. The scoliosis disappears with the relief of pain. But the treatment of nerve root irritation and pathologic disks is not within the scope of this paper.

PERSONAL

My own interest in scoliosis was roused when as a boy of 7 it was discovered that I had a curvature. I was taken to an orthopedic institution. Whoever has seen one of these institutions in Austria or Germany in the nineties knows that they looked and felt like a torture chamber. There I was bent over one bar, hung in another apparatus stretched in different directions on a third. Crawling clockwise and

counter clockwise and going through all kind of contortions were part of the program. And I straightened out completely.

During and after the first World War I saw, with my associates, hundreds of curvatures in the orthopedic hospital in Vienna, severe rachitic ones, and many paralytics after two severe poliomyelitis epidemics. We had an abundance of experience in putting on jackets and saw some remarkable improvements. We saw the Abbott cast come and go. We straightened severe curves on the Wullstein frame and constructed ingenious braces in an attempt to perpetuate the result. But we could not; as a matter of fact, many of the severe curves became worse after mobilization

It is the spinal fusion in proper indication and correctly done that has meant great progress in scoliosis therapy. Even with it the final amount

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BACKACHE FROM AN INDUSTRIAL STANDPOINT

CARLO SCUDERI, M.D. PH.D., F.A.C.S.*

ONE of the most complicated and perhaps one of the most confusing of all industrial medical complaints is "backache." Every year thousands of patients present themselves to the doctor with this complaint which is usually the result of an industrial injury. To say that this one symptom complex causes the loss of millions of working hours and costs millions of dollars in medical care and compensation is not an exaggeration; it perhaps represents a conservative estimate. No one has a universal solution to all aspects of this problem, but some practitioners have a better perspective and more information on this subject than others, and, consequently, with the administration of better medical care, a reduction both of the cost of medical care and the loss of working hours can be effected.

DIAGNOSIS

An early, accurate diagnosis with adequate medical care must be constantly sought for. Undertreatment and overtreatment of a backache are measures which are extravagant not only from the viewpoint of time and money but which, in many instances, are harmful to the patient.

An accurate history of the type of back strain or trauma incurred is most important. A fall from a distance is apt to produce a much more serious injury than that which may result from a simple stooping-over motion such as getting a file out of a drawer. An injury that produces its maximum pain immediately, with later improvement, falls into a different category from one accompanied by pain which becomes more intensified daily and ultimately develops into severe sciatica.

If a person has a complaint of backache sufficiently severe to necessitate seeing a doctor, that individual should be considered ill enough to require the removal of all the clothes necessary for a complete view of the back and extremities, keeping only enough covering to prevent unnecessary personal exposure. Talking to a patient for a minute or two and then giving oral medication without even having the patient remove his hat or coat is a practice which should be severely condemned.

A thorough physical examination of the back and legs includes, first of all, observation. Muscle spasm, muscle atrophy, position of the vertebral column, ranges of back motions in all directions, gait of the patient, and the manner of getting on and off the examining table are observations which should be carefully made and recorded.

Palpation of the back for points of tenderness, episacral lipomas, and

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counter clockwise and going through all kind of contortions were part of the program. And I straightened out completely.

During and after the first World War I saw, with my associates, hundreds of curvatures in the orthopedic hospital in Vienna, severe rachitic ones, and many paralytics after two severe poliomyelitis epidemics. We had an abundance of experience in putting on jackets and saw some remarkable improvements. We saw the Abbott cast come and go. We straightened severe curves on the Wullstein frame and constructed ingenious braces in an attempt to perpetuate the result. But we could not, as a matter of fact, many of the severe curves became worse after mobilization.

It is the spinal fusion in proper indication and correctly done that has meant great progress in scoliosis therapy. Even with it the final amount of correction is sometimes not great. Some of my most thankful patients have not more than 10 degrees correction. But even this is sometimes responsible for a decided improvement in appearance. The patients feel well compensated and lose the awful feeling of fatigue and strain that goes with an insufficiency of the back.

for the back and by stretching some of the ligaments or muscles beyond their normal tensile length they are torn. Naturally this area will become sore and remain tender for some time. What this back needs is rest, not manipulation and massage which tend to aggravate the condition. Early application of heat is definitely contraindicated since it produces local hyperemia with further capillary oozing and increased throbbing in the area. Avoidance of work, taping of the back, use of bed boards, and the administration of oral analgesics are all that is necessary. These patients usually feel much better in a week or ten days and can return to their former work. Heat, massage and graduated exercises are indicated only if the patient has stiffness of the back with limitation of motion. Physical therapy should be given only by a qualified physical therapist.

Major Sprains and Strains of the Back.—These injuries are associated with actual tearing of major ligaments of the back and sometimes with tearing of muscle fibers. Hemorrhage occurs into the area with subsequent swelling, well localized pain, muscle spasm, and restriction of back motion. These patients require a more rigid program of rest and immobility, and it is necessary in some cases to apply a form-fitting torso cast to achieve this goal. The cast should be worn for five to six weeks, by which time adequate healing will have occurred. It can then be removed and bed boards recommended and physical therapy begun to slowly increase the amplitude of back movements and to increase the muscle tone of the back.

Congenital Malformations of the Back with Aggravation by Trauma.—These present a real problem in industry. If a man sustains definite, irreversible aggravation of a congenital malformation as a result of an injury, then the industry, in the eyes of the law, is responsible for the complete care of the aggravation as well as the existing malformation. Usually, however, the aggravation of a pre-existing condition is not irreversible and can be successfully treated, so that at the termination of the medical care the back is in the same condition as it was prior to the injury, and the industry is responsible only for the aggravation until it no longer exists.

Honest, competent medical care is priceless under these circumstances. The various types of congenital malformations of the lower spine are numerous; however, the more common types are spondylolisthesis, spina bifida and abnormal articular facets.

Acquired Back Disabilities with Aggravation.—In this group of cases, as in the previous group, only when the aggravation of a pre-existing injury is irreversible as a result of an industrial injury should the industry be liable for the entire care. Otherwise it should be responsible only for that treatment which will enable the patient to reach a phase of well-being equivalent to that he enjoyed prior to the injury. Included in this group are the osteoarthritic spine, scoliosis of the spine, and old destructive changes of the intervertebral disks with narrowing of the interspace and pronounced marginal sclerosis of the adjoining vertebral margins. Those cases which show only temporary aggravation of a previously

existing pathological back condition respond well to the treatment outlined under minor and major sprains and strains.

the symptoms. Various types of acceptable spinal fusions are known to every orthopedic surgeon. The operating surgeon should use his own judgment as to the technical details. Following a spinal fusion a period of approximately six to eight months is necessary to obtain a solid bony union of the facets and the grafts

Ruptured Intervertebral Disk.—The ruptured intervertebral disk syndrome has made a tremendous impression on both doctors and the laity. Many believe themselves to be thoroughly conversant with the subject but few really understand it. Consequently, almost daily one sees cases diagnosed as ruptured intervertebral disk, purely because the patient has a backache following an industrial trauma

A few words of explanation will simplify the matter and refresh one's memory. It is well known that the intervertebral disk is a cushion or a shock absorber composed primarily of fibrocartilaginous material with a high fluid content interposed between the vertebral bodies. The periphery of this shock absorber is well confined by dense ligaments. Only when the posterior longitudinal ligament is torn and the annulus fibrosus ruptures into the neural canal and presses on a nerve root does it assume true clinical importance. A fact which is not too commonly known is that the intervertebral disk can herniate into the body of the vertebra, to the lateral sides of the body of the vertebra, and anterior to the body of the vertebra without producing significant clinical manifestations. The greatest number of clinically significant herniations, producing pressure on a lumbar nerve root, occur at the interspace between the fifth lumbar and first sacral vertebrae, some occur between the fourth and fifth lumbar vertebrae, and occasionally a rupture of a disk occurs at a higher level.

Objective Signs.—The nerve roots in this area are mixed nerves, carrying motor and sensory fibers. Naturally, when pressure is brought to bear on such a nerve, pain along the sciatic nerve becomes an outstanding and persistent subjective symptom. Slowly, as changes occur in the nerve filaments, the first objective sign—areas of hypesthesia and later anesthesia—can be carefully plotted out on the legs and foot. Owing to the direct pressure on the motor fibers, pain, and lack of sufficient use of the leg, the second objective sign, atrophy of the thigh and calf muscles, becomes detectable. This can be accurately and simply determined by taking comparable measurements of the thighs and calves of both legs. Because of the decreased function of the sensory and motor fibers as a result of pressure on a mixed nerve, the reflex arc is disturbed in its efficiency, its function becoming either impaired or completely abolished. A third cardinal objective symptom now comes to the fore, a decrease or absence of the Achilles reflex. Thus, if I may be permitted to repeat

myself, in a typical case of ruptured intervertebral disk the following cardinal triad of objective symptoms is present:

1. Hypesthesia or anesthesia that follows a definite anatomical nerve root pattern.
2. Atrophy of the thigh and calf muscles, slight if the pressure is of short duration and marked if the pressure has been of long duration.
3. A decrease or absence of the Achilles reflex.

Sometimes all three of these objective findings are not prominently present, but careful and repeated examinations will rarely fail to show all three at the same time in a case of ruptured intervertebral disk with nerve root pressure.

Localization of the Lesion.—Because of the overlap of origin of the nerve filaments that arise in the spinal cord and descend into the lumbosacral plexus, one cannot definitely and accurately localize the exact interspace where the rupture has occurred by a clinical examination only. Exact localization can best be made by myelographic studies, using 2 cc. of pantopaque. Fluoroscopic and x-ray studies of this nature are efficient and simple. Usually all of the pantopaque can be removed after the x-ray study, but if some is left behind it should not cause grave concern since it is nonirritating and is eventually absorbed. As in all x-ray diagnostic studies, there is an element of error in the interpretation of the findings, but the percentage of inaccurate diagnoses should be less than 3 per cent in the hands of experienced persons. I feel strongly that, because of the possibilities of error in the clinical diagnosis and the difficulty of localizing the lesion, rarely should a patient be operated upon for a ruptured disk unless pantopaque studies are made and show a definite intervertebral filling defect. The indiscriminate removal of several laminae to explore the anterior surface of the neural canal is to be severely condemned because it not only adds an unnecessary element of danger, but weakens the back structurally. I am fully aware of disagreement with these views, but I believe that further study, experience and careful review of past cases and their results will slowly thin out the ranks of the opposition.

Indications for Associated Spinal Fusion at Operation.—If a ruptured disk exists, its removal is indicated before irreparable damage occurs to the nerve root. The technical details of its removal are well known to all experienced in this field and are not within the scope of this discussion. One point of considerable importance concerning which there is great variation of opinion is whether or not an associated spinal fusion should be performed. One should not be swayed by tradition, geographic location, or hysteria on this subject. A rational solution will eventually be reached on this question only after years of careful study. From the extremes of no spinal fusions advocated by neurosurgeons to spinal fusions in all surgically treated cases advocated by some orthopedic surgeons, there must be a happy medium. I do not wish to imply at all that my views are the only correct ones, as I recognize all too keenly some of their shortcomings, but I feel that unless there is definite evidence of associated back instability prior to the operation, or as the result of bone removal

at the time of operation, a spinal fusion is not indicated unless one fails to find a ruptured disk in the explored area. A spinal fusion may then be done in the hope that the stabilization of the lower back will have a beneficial effect.

Some of the more common indications for an associated spinal fusion at the time of the removal of the disk are: (1) spondylolisthesis; (2) prespondylolisthesis; (3) spina bifida; (4) abnormal, inefficient lumbosacral facets; (5) marked osteoarthritis of the lumbosacral area; (6) excessive bone removal at the time the disk was removed; (7) a loose lamina of the fifth lumbar vertebra found under direct vision at the time of surgery of the ruptured disk.

Postoperatively, patients can return to light work in three months and hard work in six months. Prolonged litigation is not conducive to a rapid recovery in these cases. A relatively early settlement is most beneficial.

Psychosomatic Backache.—Psychosomatic backache is a real problem in industrial cases. For this reason, everyone who treats backache should have some knowledge of psychiatry in order to avoid elaborate or prolonged treatment. Operation in these cases should certainly be avoided unless the indications are beyond any question of error, since the patients never get better, never move out of the neighborhood, outlive the doctor, and forever haunt him in his practice. This group of cases follows a more or less definite pattern. Patients complain profusely and go into the minutest details. In spite of their complaints the back and leg muscles appear normal. There is no well localized point of pain, it varies during the examination and from examination to examination. There is hypesthesia of the whole leg throughout its entire circumference. The patients seem to enjoy their poor health because they now have an excuse for not doing the things they have always hated, such as arising in the morning, working for a livelihood, and waiting on themselves. Suddenly they can stay in bed as long as they wish, they do not have to work, and they can have others wait on them. What an ideal situation! Why get better? Most unfortunate are the family, the doctor and the industry inflicted with one of these constitutionally inadequate persons.

Backache from Other Causes.—One should not forget that backache is also caused by diseases other than those of the musculoskeletal system. These include such conditions as obesity, endocrine disturbances, diseases of the genitourinary and reproductive system, and diseases and tumors of the rectum and sigmoid. It should also be remembered that for centuries people suffered and were cured of sciatica before Mixter and Barr awakened the medical profession to the presence of a ruptured intervertebral disk.

graduated exercises in the later stages, do much to mobilize the semi-rigid back. Where prolonged inactivity or immobilization has caused a fibromyositis of the back, gentle manipulation under light anesthesia frequently gives remarkably favorable results. This procedure should be kept in mind when normal spine flexibility is not regained under more conservative treatment.

Horse trainers and athletic trainers have known for generations that an injured horse or athlete cannot go back to full activity on the day his injury is believed to be cured. A breaking-in period or a program of rehabilitation is followed so that each day an increasingly difficult task is undertaken until such a time as the horse or the athlete has regained the ability to undertake unrestricted activity. Why has industry failed in many instances to do likewise? Two reasons suggest themselves: first, because industry does not have a sufficient variety of jobs to permit giving an employee a graduated type of work until he is able to do unlimited work as he did formerly, and secondly, because it does not have adequately trained personnel to intelligently undertake "job reclassification." A suggested pattern for job rehabilitation might be divided into the following four groups: (1) light work, part time; (2) light work, full time; (3) heavy work, part time; (4) heavy work, full time. This rehabilitation program could be terminated when the patient has reached the period of rehabilitation that places him in his former category.

Unfortunately, industry will forever have litigants who will be eternally prolonging law suits and constantly coming in with new claims, and those so well classified in the army as "gold-bricks," who will never adequately carry their load in life. On the credit side is the fact that most employees who have backaches as a result of an industrial injury are co-operative, intelligent, and anxious to get back to work. Let us see that they get competent medical care and give them the best possible result in the shortest period of time.

AMPUTATIONS AND PROSTHESES

WILLIAM A. LARMON, M.D.*

THE objective of successful amputation surgery is rehabilitation of the patient to as complete a degree as possible. To this end a definite program must be followed, including selection of a proper site for amputation, a practical surgical procedure, selection and fitting of a suitable prosthesis, and the physiologic and psychologic recovery of the patient. The responsibility of the surgeon does not end with the postoperative period, but must continue until rehabilitation is complete.

It is the purpose of this paper to emphasize the accepted principles of amputation surgery and prosthetic devices as a step toward rehabilitation.

GENERAL PRINCIPLES

The upper and lower extremity present entirely different amputation problems. The functions of the lower extremity are propulsion and weight bearing. The functions of the upper extremity are sensory perception and dexterity. Re-establishment of these functions is the guide to the surgery which is undertaken.

Since an amputation stump is a lever activated by muscles attaching at its proximal portion, the longer the lever, the greater the control and excursion of the prosthesis. Thus, conservation of length is important. Definite sites of election for amputation are preferred in the lower extremity (Fig. 100). These sites are dictated by the requirements for weight bearing and propulsion. Certain areas are definitely contraindicated, as amputation here results in deformity and the limb will not tolerate weight bearing or a prosthesis.

Lower extremity stumps are primarily end-bearing, side-bearing, or ischial-bearing, or a combination of the three. Selection of the type of stump will depend upon the conditions requiring amputation and the occupation of the patient. End-bearing stumps are preferred when considerable walking and standing is required. This type of stump differs from the side-bearing stump, in that the operation must be performed through a flaring cancellous portion of the bone and the stump must be covered by skin adaptable for weight bearing. The wide area of bone is necessary to distribute the weight to be borne over the maximum area of the stump.

Amputations in the upper extremity demand extreme conservatism.

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Any portion of the hand that can be reconstructed to perform the functions of grasp and sensory perception is far superior to any prosthesis. Loss of all the fingers and the thumb does not warrant amputation at a higher level, inasmuch as reconstruction procedures are available which

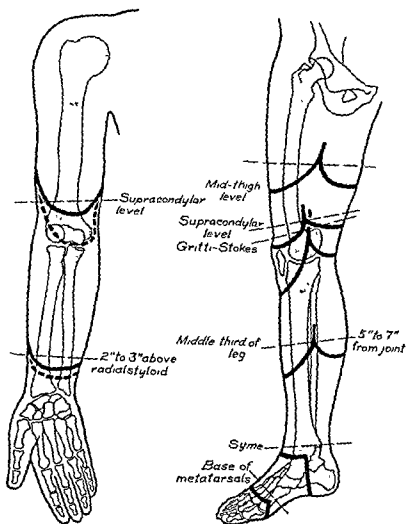


Fig. 100.—Amputation levels. Sites of election indicating flaps and levels of bone section. Stippled areas about the joints indicate sites through which amputations are usually contraindicated

will greatly aid restoration of function. Thus conservation of length in this instance is of particular importance.

The ideal stump in both upper and lower extremities should be pain free. It should be well molded and, usually, conical in shape. It should be covered with skin and subcutaneous tissue adequate to meet the demands made upon it. The scar should be minimal and so placed that it will not interfere with the wearing of a prosthesis. The skin and subcu-

taneous tissues should be freely movable and must be under normal tension over the bone. Circulation must be adequate. The stump itself should be freely movable and well controlled by adequate musculature. All these conditions must be met to ensure a completely satisfactory stump.

PRINCIPLES OF SURGICAL TECHNIC

The surgical principles in amputations of either the upper or lower extremity are the same. A tourniquet is used whenever possible to control blood loss and to facilitate the surgical procedure. It is not used in peripheral vascular disease, as the trauma to already damaged vessels may precipitate circulatory failure in the stump.

When amputation is necessary because of trauma or infection, the problem of primary closure versus open treatment arises. In the presence of spreading infection the open method is always indicated, as the guillotine amputation. When trauma results in amputation, we are often forced to accept an arbitrary level and make use of the remaining viable tissue. If the interval between injury and surgery has been prolonged, the safest method is the guillotine amputation; the decision will be guided by the time interval (usually six to ten hours) and the degree of damage to surviving tissues. The guillotine amputation is only a temporary measure, as a rule, performed to avoid or control infection. Usually revision is required at a later time at the site of election. This amputation, therefore, should be done at the most distal level of viable tissue. Skin traction should be applied immediately.

When amputation is performed at the site of election, the skin flaps are cut so that combined they are slightly less than, or just equal to, the diameter of the extremity at the site. Skin and subcutaneous tissues are sutured under normal skin tension; redundancy and excessive tension are avoided. The flaps are outlined so that the suture line will be terminal in the upper extremity, and terminal or slightly posterior in the lower extremity. The fascia is divided at the skin level and, whenever possible, is reflected with the skin and subcutaneous tissue, this being the major bone covering. Muscle is severed distal to the bone, so that retraction will draw the remaining muscle to the bone level. Muscle should not cover the bone end, as a rule, as it adds to scarring, tends to make the stump redundant and bulbous, and may interfere with the circulation in the flaps. In most cases it does not provide padding for the bone.

The bone is sawed through cleanly to avoid splintering, and care is exercised to avoid periosteal stripping by retraction. Some authorities advocate removal of one-fourth inch of periosteum to avoid spur formation. This procedure, however, may result in necrosis of the bone end through interference with the blood supply. The marrow cavity is not disturbed. Sharp corners of bone may be removed with a rasp or sharp osteotome, and bone dust is removed by saline irrigation.

Many authorities favor ligation and injection of absolute alcohol into the nerve end to avoid the formation of neuroma. All nerve stumps heal

normally by formation of neuromas, and pain is not produced by the neuroma per se. A painful neuroma is caused by excessive scarring of the tissue about the neuroma, which subjects it to stretching, tension or compression, thus producing the painful stimuli. If the neuroma is protected by normal tissues and has not been unduly traumatized, it should not be painful. We prefer to pull the nerve gently down below the muscle and sever it with a sharp knife. The normal tension will then retract the nerve above the terminal end of the stump into normal muscle planes, where minimal scarring occurs.

Major blood vessels are doubly ligated, one ligature being anchored to the vessel wall to prevent slipping. Vessels are cut at the muscle level.

The bone is covered by skin, fascia and, in some cases, tendon, when the wound is closed. Closing heavy muscle masses over bone only adds bulk and scarring to the stump and should be avoided. The muscle atrophies and adds still further to scarring, often producing a redundant, thickened, painful stump, by interference with circulation and nerve supply. Scars situated between bones of either the upper or lower extremity are to be avoided whenever possible, as retraction between the bone ends occurs. Extensive lateral scars in the thigh, over the anterior tibial condyles, or on the plantar aspect of the foot or palmar surface of the hand are particularly undesirable, because of the pressure to which they are subjected.

A minimal amount of suture material is buried, excessive suturing of fascia and subcutaneous tissue may cause circulatory failure in the flaps.

Soft rubber drains are used when large muscles are severed, as a certain amount of serum will collect under the flaps, even though an adequate pressure dressing is applied. Drains should be removed in twenty-four to forty-eight hours, as they are a potential source of infection. Dressings are done infrequently thereafter. A snug pressure dressing is applied with an elastic bandage in all cases.

Splints are used to prevent deformity and aid in wound healing, in all cases in which deformity is likely to occur.

AMPUTATIONS OF THE LOWER EXTREMITY

The Toes and Foot.—Except in the case of the great toe, the entire

closed. In the case of the little or great toe, disarticulation is the same; however, the lateral prominence of the fifth, or the medial prominence of the first metatarsal head is shaved flat to the shaft, to avoid bunion formation.

When the second toe is removed, hallus valgus of the great toe may

All the toes may be removed without greatly interfering with weight bearing. The scar should avoid the plantar aspect and is preferable on the dorsum, but may be terminal. A satisfactory weight-bearing foot is

possible if amputation preserves the metatarsal bases. Amputation proximal to the tarsal metatarsal joints invariably results in deformity of the heel due to muscle imbalance. For this reason the Chopart and Lisfranc amputations are condemned. The deformity is usually plantar flexion and inversion of the stump. Adaptation to a prosthesis is difficult and breakdown of the skin is common.

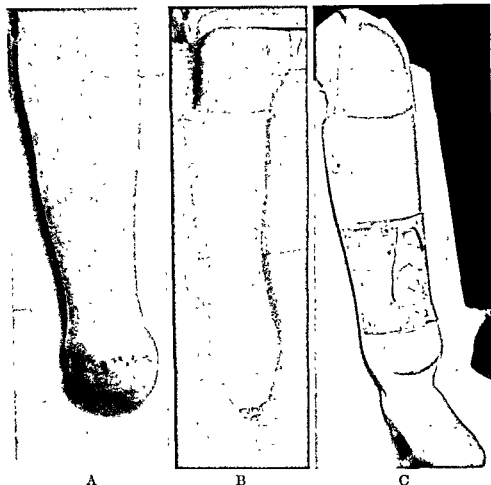


Fig. 101.—A, Syme stump. The location of the scar is anterior in the region of

molded leather lacer connecting to the ankle by metal bars.

SYME AMPUTATION.—Amputation of the foot proximal to the metatarsal bases demands the Syme level as the most distal practical area. The amputation is through the cancellous tibia and fibula at the joint level. The weight-bearing skin of the heel forms the flap. The stump is end-bearing. Unfortunately, this procedure is possible only when there is absence of infection, normal heel skin is present, and circulation is adequate. The advantages of a completely end-bearing stump are many and, in addition, the stump is long enough to permit barefoot walking. However, the prosthesis produces a bulky ankle, so that, for cosmetic reasons, women usually prefer amputation through the midcalf (Fig. 101, A).

Technic of Syme Amputation—The incision is transverse at the joint line to the anterior borders of the malleoli, thence around the bottom of the foot horizontal to the long axis. The astragalus is disarticulated and removed with the os calcis by careful dissection close to the bone. A cup-shaped heel flap results. The tibia and fibula are sectioned one-eighth inch proximal to the joint surface. The flap is sutured anteriorly over the tibia. The flap is slightly redundant and "dog ears" are present, however, shrinkage occurs rapidly. Because of its tendency to displace, the

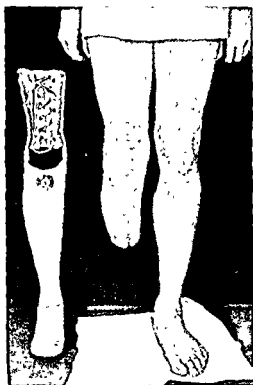


Fig. 102—Below-knee stump and prosthesis. The stump is maximum length and will require more shrinking before fitting (Medical Illustrations Laboratory, Hines Veterans Administration Hospital, Hines, Illinois)

flap must be carefully centered over the bone when dressings are applied. Drains are used in the corners of the wound.

A plaster pylon is applied after four weeks, and weight bearing is allowed for four more weeks before the permanent prosthesis is fitted (Fig. 101, B, C).

Midleg Amputations.—When a higher amputation is necessary, the site of election is 5 to 7 inches below the knee joint (Fig. 102). A stump longer than 7 inches is undesirable because of vascular inadequacy, and because of the difficulties encountered with the prosthesis. A stump as short as 2 inches is useful, and by careful fitting of the prosthesis, knee

joint action can be preserved. Occasionally, a stump even shorter than 2 inches may be fitted with a bent knee prosthesis, the patient bearing weight on the patella.

The mid-calf stump is a side-bearing stump, and no pressure is tolerated on the end. An extremely short stump may require a partial ischial weight-bearing prosthesis.

Technic.—The anterior flap is made slightly longer than the posterior one, so that the scar will fall slightly posterior. The deep fascia is not disturbed anteriorly, as it is in intimate contact with the tibial periosteum. Posteriorly it is reflected with the skin and subcutaneous tissue. Muscles are sectioned to allow for retraction to the end of the bone. The anterior tibia is beveled and the fibula is sectioned $1\frac{1}{2}$ inches above the tibia. The fascia and skin only are closed over the bone.

When amputation is performed at a level slightly higher, it may be necessary to bevel the gastrocnemius muscle to secure a conical stump. Should the stump be shorter than 3 inches, the fibula is removed in its entirety.

A posterior splint and pressure dressing is applied with the knee in extension to prevent flexion contracture until the wound is healed.

Amputation Above the Knee.—Knee joint disarticulation should be avoided.

Amputations above the knee joint are of two types, end-bearing and ischial weight-bearing. The Gritti-Stokes amputation is the classical end-bearing stump. Several modifications have been made in technique, but the principle is the same. Amputation is through the cancellous bone of the condyles. An amputation through cortical bone cannot be well adapted for full end-bearing, as the small sharp area of bone will act like a punch against the skin and prosthesis. The Gritti-Stokes amputation makes use of the patella, patellar tendon and prepatellar skin, which is well adapted to weight bearing as the covering for the bone.

Technic.—The incision is made over the center of the medial and lateral condyles, curving downward and anterior to 1 inch below the patella. The incision is carried through all structures down to bone at the same level. The posterior flap is outlined just above the flexion crease. The cartilage and subchondral bone is removed from the patella. The condyles are sectioned at the adductor tubercle. The patella is approximated to the femur with sutures. The patellar tendon is then sutured to the fascia of the hamstring muscles and the wound is closed.

An elastic spica pressure dressing is applied. The turns of the spica bandage are carried around the pelvis, in such a manner as to hold the thigh in adduction and extension.

Tenoplastic Amputation.—The tenoplastic amputation differs from the Gritti-Stokes in that the patella is removed and the tendon alone is used to cover the bone. This permits end bearing, and the absence of the patella prevents displacement—a common complication in the Gritti-Stokes amputation (Fig. 103).

Amputation Proximal to the Femoral Condyles.—Amputation above the condyles is done through cortical bone approximately 4 inches above the joint line (Fig. 104). This allows for normal location of the knee control mechanism in the prosthesis. The technic is similar to other thigh amputations; however, a thin layer of muscle is often drawn over the bone when the anterior and posterior fascia is sutured, as this prevents undue muscle retraction

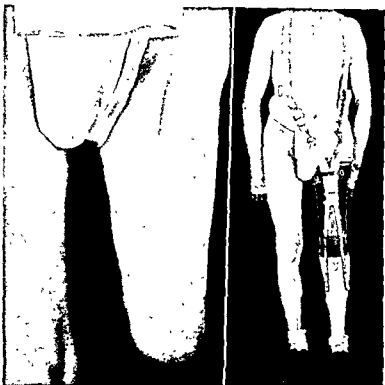


Fig. 103 —*Left*, Tenoplastic amputation with full end-bearing stump *Right*, End bearing above knee prosthesis. Molded leather socket equipped with side knee joint. This prosthesis is suspended by shoulder straps, but a pelvic band may be used (Medical Illustrations Laboratory, Hines Veterans Administration Hospital, Hines, Illinois)

Above this level all length possible must be conserved. Muscle imbalance resulting in flexion abduction deformity is prone to occur with a short stump. Power and control of the prosthesis is lost as the lever is shortened. A stump as short as 5 inches below the trochanter can be made and fitted in the usual manner.

Amputation Near the Hip.—A stump shorter than 4 or 5 inches below the trochanter may become flexed and abducted to a degree that makes fitting a difficult problem. Above this level the incision is the racquet type, with the handle of the racquet anterior and encircling the leg 2 inches distal to the peroneum. The shaft of the femur is removed at

the base of the trochanter. Disarticulation should be avoided and preservation of the head, neck and trochanter is necessary to form a well-rounded buttock. These structures add stability and control to the stump. Following disarticulation or section at the trochanter, the muscles must be drawn together to eliminate dead space and aid in molding the stump.

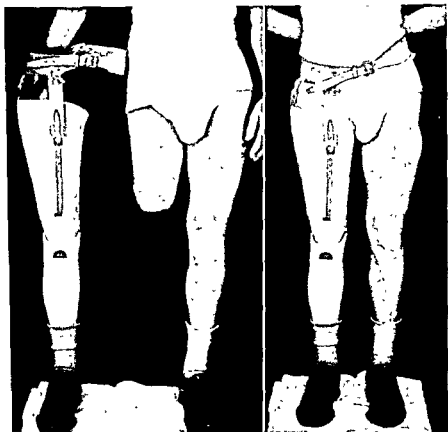


Fig. 101—*Left, Thigh amputation above the femoral condyles. Right, Conventional above-knee prosthesis with pelvic band. Suspension is through the hinge joint anterior to the trochanter. The anterior strap is connected to the knee mechanism and aids in extension. (Medical Illustrations Laboratory, Hines Veterans Administration Hospital, Hines, Illinois)*

A saucer-shaped socket or tilting table prosthesis must be used with its many disadvantages and resultant difficulty in walking.

AMPUTATIONS OF THE UPPER EXTREMITY

As stated previously, every bit of tissue that will survive should be preserved in the hand. There is no substitute for the ordinary functions of the hand. However, when parts of the hand are lost many reconstruction procedures have been devised to make use of remaining structures. Thus there are few sites of election for amputation in the hand, and the problem in each case will vary.

Finger Amputation.—Finger tip amputations following trauma are

best covered by split-thickness or pedicle skin grafts immediately. No attempt is made to secure flaps for closure, as unnecessary shortening results. If amputation occurs through the nail bed it should be removed, as a deformed nail may cause trouble by growing into the soft tissues. An ideal skin flap with the scar on the extensor surface is frequently impossible to obtain, and length must not be sacrificed to secure the ideal. If bone and tendons are exposed, a pedicle graft offers a solution without resorting to radical amputation.

Amputation Proximal to the First Phalanx.—The tendons should be allowed to retract and reattach in the sheath. Drawing the tendons together over the end of the bone produces a painful stump and limits flexion and extension in the remaining fingers. If done through the joint, the condyles are narrowed to the width of the shaft to prevent a bulbous stump.

At the Metacarpophalangeal Joint.—The incision is racquet-shaped, similar to that for the toe. When the fifth and index fingers are removed at this level a better cosmetic and functional result may be obtained by oblique section of the metacarpals through the midshaft, thus tapering the palm into the base of the remaining fingers.

When the middle two fingers are amputated at the metacarpophalangeal joint, the metacarpal head must be preserved. Removal of the head results in rotation of the remaining fingers toward each other, so that overlapping occurs in flexion. If this occurs it may be necessary to remove the entire metacarpal and narrow the hand. This procedure should be avoided, particularly in the middle metacarpal, which serves as the attachment for the adductor of the thumb and its removal causes weakening of grasp.

The Thumb.—Loss of the thumb produces a serious handicap. The function of apposition is lost and the hand becomes a hook. Every effort toward reconstruction should be made before resorting to amputation. Even a small nubbin of thenar eminence is of value as a prominence against which the fingers can be apposed. The same principles apply to the thumb as to the fingers. If disarticulation at the metacarpophalangeal joint is necessary, the first metacarpal may be phalangized by freeing the attachment of muscles distally and creating a cleft between the palm and metacarpal. Usually skin grafting is necessary to close the defect that is created.

If all the fingers are lost, similar phalangization may be done with the remaining metacarpals, and a lobster claw hand made. The function is far superior to that of a prosthetic hand.

Amputation Through the Carpal Bones.—When amputation of the metacarpals is necessary the carpus may be preserved and furnish limited function. The tendons of flexion and extension of the wrist, which insert into the metacarpal bones, must be sutured to the joint capsule to preserve active motion. Pronation and supination are also preserved by this procedure. Contrary to popular belief, this is a very useful stump. Sensation and fairly complete motion are retained, and limited grasp can be

accomplished by a prosthesis which furnishes a fixed point of apposition for the carpal bones. Fitting such a prosthesis is an individual and difficult problem.

Disarticulation of the Wrist.—Disarticulation at the wrist preserves almost complete pronation and supination. However, the stump is irregular in shape, the bony structure is prominent and circulation is hazardous. The stump has the advantage of adaptability to a prosthesis requiring a minimum amount of suspension above the elbow. However, it is difficult to fit and generally amputations at a higher level are preferred.

Site of Election in the Forearm.—Above the wrist joint, the site of election is 2 to 3 inches above the radial styloid process. All length above this area should be conserved. Stumps as short as $1\frac{1}{2}$ inches are useful and can be fitted with a prosthesis. Loss of flexion and extension of the elbow is a serious handicap, and limits the use of a prosthesis tremendously.

Technic.—The flaps are made equal in length. The scar is terminal, but should not be situated between the bone ends as retraction will occur. The length of the flaps should equal slightly less than the diameter of the forearm. The deep fascia is reflected with the skin. The muscles are sectioned just distal to the bone to allow for retraction. The bones are equal in length. Skin and fascia only are sutured. When the forearm stump is excessively short a slight increase in length may be obtained by section of the biceps tendon at the elbow; a slight loss of power will result.

Short stumps particularly should possess a minimum of soft tissue, as excessive tissue blocks flexion when a prosthesis is applied and produces an unstable stump. Flexion contractures are prone to occur and should be prevented early.

Disarticulation at the Elbow.—This procedure produces a powerful lever and because of the contour minimal shoulder suspension of the prosthesis is necessary and its rotation is better controlled. The disadvantages are prominence of the condyles which causes fitting problems, and possible soft tissue failure through hard usage. The flaps may be fashioned in any convenient manner, preferably anterior and posterior. The biceps and triceps tendons are sutured over the end of the bone.

Supracondylar Arm Amputation.—The problems here are similar to those encountered in the above knee amputation. The site of election is just above the condyles, about 1 inch proximal to the joint line. Above this area all length possible must be retained, as decrease in length leads to loss of power and control. The skin flaps are anterior and posterior, and of equal length. The triceps and biceps tendons may be utilized for bone covering together with the deep fascia. A stump as short as 2 inches below the anterior axillary fold may be fitted with the conventional above-elbow prosthesis. Any prosthesis requires suspension from the shoulder.

Amputation in the Shoulder Region.—A stump shorter than 2 inches

below the axillary line requires a racquet incision, with the racquet handle centering over the acromion process. The head and neck of the humerus should be preserved and disarticulation should be avoided. Preservation of these structures retains a rounded shoulder which provides a prominence for more comfortable fitting and better function.

Following removal of the bone, the muscles are drawn together as in the region of the hip, to mold the shoulder and eliminate dead space.

This amputation requires shoulder cap suspension and the prosthesis is of very limited use.

Cineplastic Amputation.—Cineplastic procedures have proved of definite value in the hands of Kessler and Nissen and Bergmann in this country. The cineplastic operations were devised to permit activation of a prosthesis by the muscles in the stump itself. The procedure consists of constructing tunnels in the stump, incorporating a portion of the muscles, usually of flexion and extension. By appropriate transmission of muscle power from these tunnels the prosthesis is activated. There are the definite advantages of positive control of the prosthesis by muscles accustomed to performing these functions. In addition, the patient develops a definite proprioceptive sense through the muscle tunnels and thus more nearly approaches the normal.

The stumbling block to wider use of the procedure has been the difficulty, in developing an adequate prosthesis.

POSTOPERATIVE MANAGEMENT

The general principles of postoperative care are followed in amputation surgery.

Dressings are done infrequently following the removal of drains in twenty-four to forty-eight hours. Sutures are removed in ten days to two weeks.

Molding of the stump to a conical shape begins immediately by bandaging with elastic bandages. The muscles and soft tissues must be shrunk before fitting the prosthesis. Several turns are taken over the end of the stump and the remainder of the limb is bandaged to above the proximal joint. Deformities are prone to develop during this period. The common deformities are flexion of the knee, flexion abduction of *the hip*, flexion of the elbow and adduction of the shoulder. These may be prevented by early muscle exercises and proper bed posture to counteract the tendency to deformity. Massage and pounding of the stump are contraindicated, as they add trauma to healing tissues and do not toughen the stump. Weight bearing and use are the best forms of physical therapy.

PROSTHETIC DEVICES

Prostheses are mechanical devices designed to substitute lost function or to minimize cosmetic disability. During World War II a research program in the field of prosthetic devices was carried on by the National

Research Council, in co-operation with others. Since that time the program has been continued by the Veterans Administration. From this research work has come many improvements in design and materials used in prostheses.

Lower Extremity Prostheses.—A prosthesis for the lower extremity must be strong to permit weight bearing, but light enough to permit function without undue effort. It must fit the stump comfortably and be free from pressure and friction areas. The weight must be distributed through areas which will endure prolonged walking and weight bearing (Fig. 103, *B* and 104, *B*).

Alignment and Fitting.—The alignment of the artificial leg and the fitting of the socket to the stump are the factors which determine comfort and ability of the amputee to use the prosthesis. The materials and design of the mechanical parts determine the durability, ease of walking and ease of manufacture.

Alignment of the leg is the relationship of the levers of the prosthesis to the joints and to the stump. Generally, the alignment of the prosthesis should approach that of the remaining lower extremity.

The Foot and Ankle.—The normal axis of joint motion must be followed closely in the prosthesis. The metatarsal phalangeal joint axis is diagonal across the foot outward and toward the heel, about 8 degrees from the horizontal. The joint in the foot piece should correspond with this axis.

The normal axis of the foot on the ankle joint is 15 degrees of external rotation. This outward rotation is duplicated between the foot and ankle hinge of the prosthesis. Attempts have been made to reproduce inversion and eversion of the foot; however, these motions have usually caused instability. Improper alignment of the joint in the forefoot and at the ankle will produce rotatory movement of the prosthesis on the stump, with resulting friction and irritation.

Dorsi- and plantar flexion of the foot piece at the ankle are controlled by rubber bumpers inserted in front and back of the ankle joint. These bumpers prevent overextension or flexion of the foot and maintain the proper degree of slight plantar flexion. The back one prevents the foot from sudden plantar flexion when weight is placed on the heel in walking. The forward bumper maintains plantar flexion which aids in extension of the knee and prevents sudden dorsiflexion which would allow the knee to buckle. Improper adjustment may cause the knee to buckle, the sole of the foot to slap against the floor as in drop foot gait, or undue effort is required to rise over the ball of the foot.

The Knee Joint.—The knee joint axis is located slightly posterior to the axis of the leg. This allows the knee to lock in extension and permits the tibia to glide posterior on the femur in flexion. If the side hinges in below-knee prostheses are located improperly, the stump will ride up out of the socket in flexion and produce pressure on the stump end. A great deal more effort is required to maintain extension in walking.

There is normally about 10 degrees of knock-knee in the leg.

gree of knock-knee moves the center of gravity more nearly over the foot. The degree of knock-knee is determined from the opposite leg. Failure to incorporate this angulation in the prosthesis will produce lateral swaying when walking, as an attempt is made to throw the center of gravity of the body over the axis of the leg.

Above-knee amputations require an artificial knee joint. Much experimentation has been done to reduplicate the normal knee action and control of flexion and extension. Attempts are being made to produce positive locking of the knee in extension when weight is borne with, however, but limited success. Hydraulic mechanisms to control flexion and extension are also in the process of development and hold much promise for more positive control. These devices will enable the amputee to walk inclines and stairs with greater ease and confidence.

At present, however, the usual method of controlling knee joint action is the placement of the joints posteriorly and the use of a braking mechanism. The adjustment of the brake, extension straps and check straps when they are used is important. The proper adjustment is necessary to prevent unexpected buckling and to permit smooth flexion and extension. Too loose brakes or check straps will allow sudden extension of the knee with a sharp snap, which produces shuddering and whipping of the leg on walking. When too tight, complete extension may be slow and buckling may result.

The Hip Joint.—Hip joint control and suspension of the leg is provided by a pelvic band and joint, or by shoulder strap suspension. The more common at present is the pelvic band and hinge. Again alignment must correspond to the axis of the hip joint, which is perpendicular to the center of the acetabulum. Thus the joint for pelvic control must lie considerably anterior to the trochanter, not over it. Failure to align the joint properly again produces rotatory motion in the prosthesis.

The length of the prosthesis should be equal to the normal leg so that the pelvis is level when standing. It is permissible to make the leg slightly shorter to allow extension without the foot scraping the ground.

The stump must be fitted in a relaxed position and the socket then aligned with the prosthesis, to prevent unwanted pressure being exerted on the stump.

Normally the mid-calf stump is fitted in slight flexion to throw the weight on the anterior upper flare of the tibia.

The above-knee socket may require fitting in slight flexion and abduction, as this is the normal relaxed position.

When faulty fitting and alignment is done, fatigue and pressure or friction areas develop. The common areas in below-knee stumps are over the tibial condyles, where the weight is borne. Occasionally pressure is exerted over the anterior lower portion of the tibia. Bulging of the popliteal structures over the posterior rim of the socket may also cause pressure and edema.

Above the knee, difficulty may be encountered at the ischium and attachment of the adductor muscles, usually due to pressure or friction. Relieving of the socket in these areas may help overcome this. Occa-

sionally the lateral thrust of the stump in walking will produce pressure and friction on the anterolateral distal area of the stump.

On the medial upper aspect of the thigh, the tissue may bulge over the top of the socket to produce a roll of tissue. Undue pinching of the adductor roll may cause breakdown.

The Suction Socket.—The suction socket has been used in this country since the last war, and is still undergoing experimentation by the Veterans Administration. The limb is available commercially for civilian

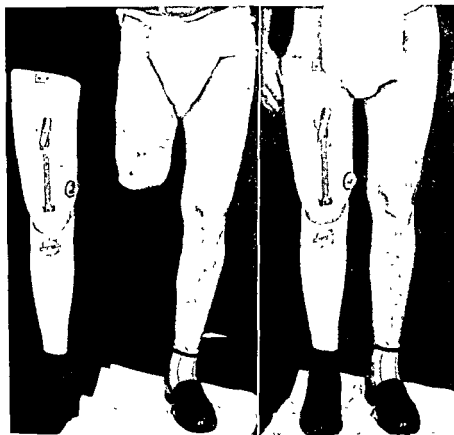


Fig. 105 —*Left*, A supracondylar amputation and the suction socket prosthesis. The socket is airtight and the negative pressure is controlled by the valve located anterior and medial. *Right*, Patient using suction socket. The strap anterior is part of the knee joint control and is a conventional type. The prosthesis differs from the conventional type only in the socket which is airtight. Suspension from the stump is affected by negative pressure in the socket. Notice the absence of shoulder straps and pelvic band. No stump sock is worn. (Medical Illustrations Laboratory, Hines Veterans Administration Hospital, Hines, Illinois)

patients. It is used in above-knee amputations for stumps not less than 4 or 5 inches in length measured from the perineum. It holds the prosthesis to the stump through negative pressure created in a closed socket. No stump sock is worn and the socket is in direct contact with the skin. The negative pressure or suction is controlled by a valve in the distal end of the air-tight socket. This means of suspension eliminates pelvic bands and shoulder straps, and permits greater freedom of action and more natural control of the leg. There is practically no pumping action of the stump in the prosthesis (Fig. 105).

When properly fitted the pressure in the socket alternates from negative to positive as the leg is swung, and weight is borne. The prosthesis is controlled entirely by the muscles of the stump and thus permits a more natural gait.

The device is not without potential danger, however. Excessive negative pressures may be created in the socket when improperly controlled. This negative pressure, which should not exceed 1.5 pounds per square inch, may produce troublesome edema and, when excessive, capillary rupture. These two complications may lead to serious trouble if not corrected early.

Contraindications to the use of the suction socket have not been adequately determined. However, it appears that osteomyelitis, severe scarring, and peripheral vascular disease may be contraindications. Perspiration may cause hygienic difficulties. However, this has been controlled to some extent by inserting a cloth bag of silica gel in the bottom of the socket, which is changed daily. The suction socket should be used with caution in the average case until further study has been made.

Tilting Table Prosthesis.—Extremely short thigh stumps are fitted with a saucer-shaped socket or with the tilting table prosthesis. This is essentially a socket which fits around the buttock and pelvis, the leg being suspended from the socket by a hinge. The general principles of fitting are again followed. The prosthesis is held in position by shoulder straps and is activated as a pendulum by swinging the pelvis. This action produces an unnatural gait as it is necessary to hunch the shoulder and swing the pelvis to walk.

Upper Extremity Prostheses.—Prosthetic devices for the upper extremity are many and varied, however, none substitute adequately for the lost extremity. Selection of a prosthesis will depend upon many variable factors. The patient's means of livelihood and psychologic, economic and physiologic reactions have a bearing on the problem. The prosthesis must be suited to the needs of the patient and the type will require careful consideration on the part of the surgeon. It is much more difficult to learn to use this adequately than is the case with the relatively simple leg prosthesis, and it is the responsibility of the surgeon to supervise the training phase. *Many arm amputees become discouraged and soon refuse to wear the artificial arm if such supervision is not forthcoming.*

The primary function of the arm prosthesis is grasping and carrying. This may be accomplished by means of a simple rigid hook, the split hook, or the mechanical hand. Purely cosmetic hands may be substituted in many prostheses when desirable.

The material should be light but strong, and action should be as free as possible. A combination of these characteristics is found in the newer plastic materials which are coming into prominence.

Hooks and Hands.—The split hook (Fig. 106) is probably the most useful device and permits a variety of functions. The hook is opened

by tension on a control cord connected to the opposite shoulder by a harness. Forward shrugging of the shoulder opens the hook. A spring or rubber band closes the hook when tension is released. The mechanical hand works on a similar principle, with the fingers or thumb moving; one is fixed, the other working against it. One hand operates in the reverse; tension closing and a spring opening the hand. It requires considerable training to control the prosthesis when muscles not accustomed to performing these functions are required to activate the prosthesis.

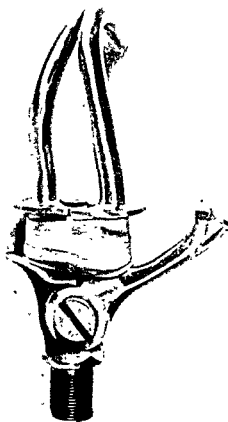


Fig. 106—Improved split hook. The control cable attaches to the lever and tension opens the hook. The rubber band about the base of the hook closes it. (Minneapolis Artificial Limb Co.)

Many mechanical hands and hooks have locking devices incorporated to ensure a firm grasp, particularly in handling tools. Adapters are also available, to substitute tools and assorted implements for the hook, and insert directly into the prosthesis. These devices are invaluable for those amputees who do mechanical work. Wrist flexion and extension is not practical in the average case, and usually are not incorporated in the prosthesis. However, chucks for holding tools, which allow for variations of angle at the wrist level, have been devised.

Pronation and Supination.—Pronation and supination are desirable features when they can be employed in below-elbow prostheses. The Northrop Aircraft Corporation developed during the war such a pros-

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proved hooks and hands, force multipliers to amplify power of grasp, hydraulically and electrically operated hands and arms, locking devices and simplified control harnesses. Many of them are still in the testing stage.

For the short below-elbow stump, a polycentric elbow joint has been devised (Fig. 108). This provides a cap for the stump, connected by levers to the arm piece which amplifies flexion and extension movements



Fig. 109

Fig. 110

Fig. 111

Fig. 109.—The Fitch dual control prosthesis. The elbow flexion and extension is controlled by a cable attaching to the shoulder harness and looping about the drum shown at the elbow joint. Forward movement of the stump causes the forearm to flex. (Minneapolis Artificial Limb Co.)

Fig. 110.—Northrop above-elbow prosthesis. This prosthesis is equipped with a locking device at the elbow. Locking and unlocking is accomplished by a downward shrug of the shoulder. The shoulder suspension and control harness is illustrated. The prosthesis is made of plastic. (Minneapolis Artificial Limb Co.)

Fig. 111.—Hosmer above-elbow prosthesis. Elbow locking device is controlled by the shoulder similar to the Northrop arm. A quick change coupling device at the wrist for changing hook devices. (Minneapolis Artificial Limb Co.)

Above Elbow.—When the elbow is amputated, the prosthesis must be provided with an elbow locking device to permit opening or closing of the hand or hook. A substitute for a locking device is coupling of the elbow joint, which produces flexion of the forearm when the arm stump is moved forward, by means of a cable mechanism. This is a valuable device in some cases; however, in the average case it restricts activity to a certain degree. The Fitch dual control arm is available in this type of prosthesis (Fig. 109).

Locking devices are of two general types; those locking manually and those locking through a control cable actuated by the shoulder.

The stronger locks are manually operated and are well suited for heavier work. The controlled locking mechanisms have been devised by the Northrop Aircraft Corporation and by the A. J. Hosmer Corporation. The elbow is locked and unlocked by a downward shrug of the shoulder and provides locking in multiple positions of flexion and extension. The Hosmer arm is coupled as well (Figs. 110 and 111).

All above-elbow amputations must be suspended by shoulder harnesses. Effective rotatory movements of the prosthesis are thus limited. The movements are confined to limited abduction, adduction, and flexion and extension at the shoulder. Harness mechanisms can be varied considerably and suited to the individual needs.

Stumps shorter than 2 inches below the axillary fold must wear a shoulder cap for suspension of the arm. The control of the movement of this prosthesis is thus greatly limited. However, through use of manually operated elbow locks some function of a hook can be obtained.

Cineplastic Prostheses.—A great deal of research has been done on cineplastic prosthetic devices. The problem has been mechanical failure of a necessarily complicated mechanism, and the economic transmission of force. Certainly, with more development, this prosthesis should prove to be a great aid to an amputee.

MANIPULATIVE SURGERY IN ORTHOPEDICS

JEROME G. FINDER, M.D.*

INTRODUCTION

MANIPULATION, by definition, is the act of treating, working or operating with the hands, especially when knowledge and dexterity are required. In a medical sense its meaning is more limited, connotating the moving, loosening or twisting of a joint to improve its range of motion. The term "bloodless surgery" has been applied also to designate manipulations which restore normal relationships, as in congenital dislocation of the hip, or restore function to an ankylosed joint, as in chronic adhesive bursitis (fibrositis) of the shoulder.

The modern medical concept of manipulation encompasses a larger meaning and includes many modalities which may be considered an extension of the limited use of the hands. A hole may be dug in the ground by scratching with the fingers, but a spade, projecting the utility of the fingers, becomes a more effective and proficient instrument of the hands. By the same reasoning, anesthesia, mechanical traction and certain forms of elastic splinting become ramifications of the art of manipulation. Finally, manipulation, outgrowing its original limitation to a joint, is now extended to include any part of the body, spine or extremities. The possibilities for the expansion of the province of manipulative surgery are great. In a broad sense conservative treatment of certain congenital lesions, as club foot and dislocation of the hip, and closed reduction of fractures and traumatic dislocations may well fall within the horizons of manipulative surgery. However, except for parenthetical mention, these conditions will not be included in this paper.

The acceptance of manipulative therapy by the medical profession as a whole has been discouragingly slow. The reasons for this indifference or reluctance to accept manipulation as a facet of medicine may be traced to several sources. First, the profession is generally unaware of the scope, indications and therapeutic value of manipulation. Second, the medical school curriculum either is inadequate or is wholly lacking in informative instructional courses in this field. Finally, the unfortunate association between manipulation and those cults which have exploited it as a complete system of therapy has prejudiced physicians against its practice.

The time has come for the medical profession to recognize the therapeutic value of manipulation and to adopt it as an integral part of the

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armamentarium of the practicing physician. As with any other therapeutic agent, the diagnosis must be correct and the indication for its use be confirmed before it is prescribed. Manipulation finds its greatest usefulness in treatment of certain forms of arthritis (hypertrophic, rheumatoid and traumatic arthritis) as they affect specific parts of the body, in some types of subluxation, and in low back disorders. Included are such conditions as fibrous ankylosis of various joints, the cervical disk syndrome, the slipped disk of the lumbar spine; subluxation of the coccyx; and fibrositis of the shoulder (frozen shoulder). The specific indications for treatment and the technic of choice will be considered in detail later.

In general, however, certain broad principles may be expounded with respect to indications and contraindications. Basically, the disease process must be in a chronic or quiescent phase of activity, the joint must be "cold." This is especially true in limitation due to rheumatoid arthritis, the disease produces progressive deformity by its continuing activity, yet manipulation is safe during a stage of remission. Contrariwise, manipulation must not be performed in the presence of acute arthritis, acute infection, sepsis, tuberculosis, osteomyelitis or neoplasm.

Recent trauma or a fracture uniting by newly formed callus also constitutes a contraindication to manipulation. It is difficult to be specific about the optimum time for manipulation after injury, but a minimum of six to eight weeks seems clinically reasonable; of course, a fracture must be solidly united by mature bone before forced movement of a joint affected by the fracture may be considered. When in doubt, it is wiser to err on the side of conservatism. Injudicious manipulation of healing tissues may superimpose fresh trauma, produce more adhesions, and prolong or increase the disability.

Anesthesia is an important adjunct to manipulation and should be used unhesitatingly when it is necessary to obtain relaxation sufficient to overcome painful adhesions. A guiding rule may be propounded to the effect that when the force necessary for effective manipulation produces pain, resistance and muscle antagonism, voluntary or involuntary, on the part of the patient, the use of anesthesia is in order. Pentothal sodium intravenously is ideal for the short anesthesia required for manipulation. For children, vinethene serves the purpose adequately.

The degree of force and the extent of manipulation depend on the disease process and its duration, the severity of contracture or deformity, the body region affected, the involvement of the soft tissues, and the status of bone density with respect to osteoporosis. As intimated previously, with few exceptions, it is wiser to undermanipulate than to overmanipulate. It is better to regain function by repeated manipulation rather than to gamble on producing severe tissue damage or a fracture by being too "thorough" in one vigorous session. Reinjury to the part or a manipulative fracture necessitates immobilization and the purpose of manipulation—to restore motion—is completely obstructed.

After manipulation, the range of motion regained must be maintained

by active and passive exercises, physical therapy, proper positioning of the limb and the use of traction, if necessary. Commonly, after the patient regains consciousness the range of motion of the manipulated joint may be somewhat less than that during the anesthesia. This loss is temporary and is consistent with the unavoidable minimal pain and spasm which are the expected sequels to manipulation. Overcoming the "adaptive shortening" (Mennell) of a restricted joint is akin, loosely speaking, to the overstretching of a normal joint. In my experience, absence of pain immediately after manipulation has been the exception rather than the rule, despite statements in the literature to the contrary.

Finally, the question of immobilization after manipulation arises. Fixed immobilization, as in a plaster cast, is never indicated, if restoration of motion is the goal. A removable splint is permissible to give ease and protection to the involved tissues and to maintain the correction when the limb is at rest from the prescribed physical therapy. Traction is an excellent form of partial immobilization, because it distracts the joint and relieves muscle spasm and yet permits motion. When combined with a hinged splint and a system of pulleys, traction becomes still more effective. Swelling of the joint may be controlled by use of an elastic bandage. In short, restoration of function of a joint depends on a delicate balance between its mobilization and rest; the physical reaction of the involved part should serve both as an index to the degree of therapy which can be tolerated, and as a warning against unduly vigorous after-care.

CERVICAL ARTHRITIS AND DISK SYNDROME (CERVICOBACHIAL PAIN).

The role of manipulative surgery in the treatment of cervicobrachial pain due to cervical arthritis and/or cervical disk syndrome is extremely valuable. In a survey of more than forty cases with the classic findings of cervical disk syndrome (pain in the shoulder, radiating to the forearm and fingers; paresthesia of hand and fingers, usually of median nerve distribution to the index finger; x-ray signs of osteoarthritis, diminished intervertebral space with large eagle-beak spurs; and loss of normal cervical lordosis), the results of traction therapy were uniformly satisfactory.

TECHNIC.—The technic of therapy is simple, but effective. It is important to establish a definite program which the patient understands and can follow. The routine consists of physical therapy in the outpatient department, supplemented by a home regimen. It is seldom necessary to hospitalize a patient, even with relatively severe symptoms, merely for the sake of more easily accessible physical therapy.

The principle of the outpatient program is the employment of physical therapy while the cervical spine is under traction. The patient is placed in the prone position on the therapy table, resting his head on a forehead pillow. A head halter is applied and connected by a rope over pulleys at the head of the table to a weight of 6 to 10 pounds. This traction is maintained while short wave diathermy is applied for twenty minutes

to the cervicodorsal spine, followed by application of a hot moist compress under an infra-red lamp concentrated on the same area for ten to fifteen minutes. Traction is released for the purpose of massage.

Three treatments are given each week and continued until relief is obtained. The patient should be warned that the first few treatments may exacerbate the symptoms because of the direct stretching of the contracted tissues in relation to the nerve roots. However, some relief is experienced about the fourth or fifth treatment, therapy should be continued until all arm symptoms have cleared up (except the paresthesia, which may persist for weeks or months after the arm pain has disappeared). On the average, ten or twelve traction therapy sessions are required to obtain sufficient relief to enable the patient to stop the professional therapy and continue with the home program alone.

The advantage of this method is that for about thirty minutes a steady pull is exerted with the neck in relative flexion and the patient is completely relaxed. This effect cannot be duplicated by hanging the patient with the Sayre overhead apparatus. The awkwardness and discomfort of the sitting or standing position produce tension states and protective spasm which offset the equivocal benefit of the suspension traction.

The home regimen includes postural considerations (a "Queen Anne" collar during the day, a contour pillow for sleep at night); physical therapy (a heating pad to the neck and upper back for one hour morning and evening), and medication, especially during the acute phase, when Empirin compound with 1 grain of codeine every three or four hours may be warranted because of severe pain. In addition, $1\frac{1}{2}$ to 3 grains of seconal at bedtime is useful.

CASE I—J. L. G., white man, aged 45, first seen on May 8, 1948, gave a history of five attacks of stiff neck, each lasting a few days, over a seven year period. The last previous attack was about three years before. The current episode began with right shoulder pain and stiffness, the pain radiated to the forearm, and tingling was noted in the index and middle fingers. He was unable to sleep at night unless propped up or sitting in a chair.

Examination.—A moderate dorsum rotundum was noted, the neck being inclined forward at a 40 degree angle. Cervical spine motion was limited, rotation to the right reproduced the pain in the right shoulder and forearm. The Adson test was negative for the scalenus syndrome.

X-Rays—The right shoulder was normal. Anterior longitudinal ligament calcification was present between the fourth and fifth, fifth and sixth, and most marked between the sixth and seventh cervical vertebrae, the space between the latter two being diminished. The cervical spine was vertical from the third to the seventh vertebra (loss of normal lordosis).

Diagnosis—Cervical osteoarthritis; disk syndrome with radicular pain.

C. **T.**

the middle finger. Continued improvement was reported after four months of active physical work.

FIBROSITIS OF THE SHOULDER

The chief indication for manipulation of the shoulder is fibrositis of the shoulder (frozen shoulder, periarticular adhesion formation, chronic adhesive bursitis), its use depending upon the chronicity of the disease. In the acute or subacute stages, forceful manipulation of adhesive contractures is contraindicated since the adhesions are in a fibroplastic state which will continue to develop and will mature into fibrous bands that will cause a recurrence of the contractures. During these stages more conservative forms of physical therapy, to be discussed later, should be employed.

The chronic form of fibrositis lends itself to manipulative therapy. Some authors contend that all stages should be treated conservatively but I have obtained the best results in the chronic stage by complete and thorough manipulation of the shoulder joint, restoring a full range of passive motion in all components of motion. Manipulation is performed under anesthesia, deep enough to obtain full relaxation, and is completed in a single procedure.

In my experience with fibrotic shoulders there is no such thing as a painless aftermath to manipulation. The reaction after any degree of manipulation is painful, requiring heavy sedation. The proponents of repeated partial manipulations must have patients of unusual fortitude; they are rare in my experience. I have discontinued multiple manipulations of the shoulder for the following reasons:

1. The pain and discomfort of a "minor" manipulation is as severe as that of a "major" procedure. A stretched adhesion remains a painful adhesion. Only when an adhesion is completely ruptured is the prognosis good for ultimate relief of pain.

2. The morale of the patient is better if he knows that one manipulation will produce satisfactory results. If he is forewarned of the need for his cooperation during the painful aftermath, he meets his ordeal with greater equanimity and determined fortitude. It is better to exaggerate than to minimize to the patient the discomfort of the immediate post-manipulation period in order to weed out patients who are dubious of their ability to stand pain and patients of known emotional instability and psychoneurotic tendencies. When the indications were physically correct, the only unsatisfactory results I observed were in patients not properly evaluated beforehand from a psychosomatic standpoint.

3. Patients refuse to permit a second manipulation.

TECHNIC.—Manipulation of the frozen shoulder is carried out as follows: When the patient is anesthetized in the supine position, an assistant passes his arms under the patient's back and with his fingertips immobilizes the lateral border of the scapula, which is fixed in the position of adduction. The operator then grasps the arm close to the shoulder. A long lever arm is to be avoided because the atrophic humerus may fracture on the fulcrum of fibrous adhesions. In routine succession manip-

The shoulder may be symptomatic for several months after manipulation, but not to a painful or disabling degree. As a rule, improvement is progressive over the months and motion is ultimately restored to a practically normal range of painless function

CASE II—T G C, white woman, aged 44, was first seen on June 21, 1946,

Examination—Motions of the left shoulder were recorded as follows. Abduction 10 degrees, humeroscapular abduction 45 degrees, internal and external rotation practically zero, flexion-adduction and posterior adduction were likewise minimal.

X-Rays—X-ray examination revealed no pathologic condition of the bones

Diagnosis.—Fibrositis of left shoulder

Course—Manipulation was carried out on August 27, 1946, with excellent release of adhesions. Routine physical therapy was given during the hospital stay of ten days, and in the outpatient department until September 23, 1946, at which time all motions were excellent, although guarded, patient could internally rotate well enough to fasten her brassiere in back. Review examination two years later revealed a normally functioning left shoulder joint

FIBROSIS OF THE ELBOW

Fibrous Ankylosis.—The notorious tendency of the elbow to become involved in excessive callus formation makes it mandatory that this joint be treated with utmost caution. The tearing, separation or irritation of the periosteum about the elbow joint subsequent to a vigorous manipulation may result in a massive callus production equal to or greater than that following the healing of a major fracture in the same region. The results of manipulative surgery of the elbow, at best, are not too good, yet judicious manipulation may improve function. Only a few adhesions should be broken at one time, and after sufficient time has elapsed to allow the joint to recover from the relatively minor trauma induced by this gentle manipulation a second manipulation may be carried out, to be followed by further stretchings, repeated as long as measurable improvement in joint motion is demonstrable

For manipulation the patient, under anesthesia, is placed supine on the therapy table with the arm abducted about 45 degrees and resting on its dorsal surface. To obtain flexion, the operator stands at the level of the patient's waist facing the head of the table and grasps the arm just above the elbow with one hand; with the other hand he grasps the back of the forearm just distal to the elbow and applies pressure toward flexion. It may prove easier to obtain flexion if the forearm is pronated or in mid-position, than if it is in the fully supinated position

To obtain extension the operator stands at the level of the patient's shoulder facing the foot of the table. If the left elbow is to be extended the operator grasps the front of the elbow (antecubital area) with his

right hand, so that his fingers enclose the ulnar margin of the elbow, leaving the thumb free to apply strong pressure over the head of the radius. Unless the radial head is held firmly during the manipulation there is danger of its being subluxated forward. Now, with the elbow firmly controlled, the operator uses his other hand to force the fully supinated forearm into extension, bearing in mind the need to apply sufficient lateral pressure to duplicate the carrying angle of the well arm.

In patients whose motion is limited in the last few degrees of extension, manipulation is indicated if pain is the chief complaint. Some of these cases probably are due to redundant synovial fibrous tissue between the olecranon and its fossa, subsequent to some previous trauma of minor degree. The technic employed is described by Mennell as "grinding the beak of the olecranon into the olecranon fossa," and consists of rocking the forearm alternately into varus and valgus position on the fixed arm as the elbow is progressively extended.

Radiohumeral Bursitis.—Manipulation has been employed successfully in the treatment of chronic radiohumeral bursitis (epicondylitis, tennis elbow). Either general anesthesia of short duration or an injection of 5-10 cc. of 1 per cent procaine solution into the zone of tenderness may be used. The technic consists of placing the elbow in full extension and then vigorously hyperextending and adducting (decreasing the carrying angle). In this maneuver it is permissible to make an exception to routine technic in that a long lever arm may be used, and the mechanics employed may approach a controlled brisk jerk. The forced hyperextension and adduction with long leverage may produce a snap which is a favorable sign, indicating a release or separation of the adherent fibrous tissues.

FIBROUS ANKYLOSIS OF THE WRIST

The complexity of the wrist joint makes it unsuitable for manipulative therapy, according to the principles already discussed. The only condition for which I employ manipulation is rheumatoid arthritis with progressive ankylosis producing a flexion deformity. In such cases, under general anesthesia, the wrist is simply forced into optimum functional position of extension and immobilized in plaster. If some motion ultimately remains in the joint after the disease is "burned out," it will be greatly enhanced by the cock-up position. However, if ankylosis progresses, as expected, to an uncompromising bony fusion, the position of function will provide greater efficiency for the handicapped fingers.

FIBROSIS OF THE FINGERS AND METACARPOPHALANGEAL JOINTS

The finger joints, in common with the elbow, are not amenable to manipulative therapy for stiffness. The delicate mechanism of the joints, the intricate interplay of synovia, capsule and investing ligaments, and the altered adaptability of excursion of the controlling tendons make these joints susceptible to injury, slow to heal, and quick to stiffen by

fibrosis. The most careful manipulation (and certainly unskilled forcing) of the joints still produces some degree of hemorrhage, which in turn, upon organization, results in a disproportionate and inordinate degree of fibrous tissue proliferation. Therefore, for all practical purposes, I have discarded forced manual technics in favor of the use of elastic traction.

Several methods are adaptable, depending on the degree of fibrosis and the particular joints to be mobilized. Traction may be obtained in several ways. The use of skeletal traction is contraindicated since it superimposes trauma to the member, produces secondary reaction in the tissues adjacent to the wire, and may open an avenue of infection. More acceptable is the use of traction through a hole in the fingernail, but this method frequently stirs up reactive changes at the base of the nail, and occasionally a nail is avulsed from its bed. The "Japanese finger trap," wire or reed, is effective, but tends to constrict the circulation. A better method is the use of finger-sized stockinette glued to the finger by Ace adhesive, which when dry has excellent holding quality. Its chief disadvantage lies in its lack of flexibility after drying. However, it may be used efficiently in most cases. When it is evident that correction is possible beyond the limits of the dressing, it may be reapplied in the new position and traction continued for further improvement.

TECHNIC—The method of choice, in my opinion, is use of the traction glove described by Bunnell and others. An unlined glove of soft leather (chamois, doeskin, kid) is fitted to the affected hand. A wire loop or a small paper clip is fastened through the tip of each glove-finger, corresponding with the fingers to be corrected. The loop or clip is then connected by means of a rubber band to the traction base. Traction may be increased by use of an additional rubber band or a shorter band. For flexion contractures, extension is obtained by use of a removable volar plaster splint to which is attached a heavy wire ring extending distal to the hand (banjo splint). The volar splint is placed over the gloved wrist and palm and held in position by an elastic bandage. When an extension contracture is present, flexion forces are obtained by bending the banjo splint volarward and proximal to the wrist. When more acute flexion is desired, especially in involvement of the *metacarpophalangeal joint*, the banjo splint may be replaced by several small hooks incorporated into the volar surface of the volar splint at spaced intervals proximal to the wrist. The traction force may be decreased or increased by adjusting the rubber band to a closer or a more distant hook, the elastic bandage may be so wrapped that any chosen hook may be exposed, while adequate fixation of the splint to the forearm is still maintained.

This technic for applying traction has the advantages of permitting its removal for the administration of physical therapy, of permitting adjustment, and of subjecting the tissues to a minimum of trauma.

LOW BACK DERANGEMENTS

Current opinion accepts the concept that the conditions known variously as lumbago, sciatica, sacroiliac strain or sprain, lumbosacral sprain, and sciatic scoliosis probably represent some form of slipped intervertebral disk.

If the mechanics of the slipped disk are visualized the rationale for manipulation becomes clear. Any posture which arches the lumbosacral spine into hyperextension, increasing lordosis, increases the lumbosacral angle but decreases the lumbosacral interspace posteriorly. By the same token the superior articular facet may ride upward, encroaching on the intervertebral notch and narrowing the interforaminal space through which the nerve root passes. If the disk is herniated posteriorly, lumbar extension increases the intradiskal pressure and favors further posterior ballooning of the extruded disk.

Almost invariably the patient assumes a forward, hunched-over posture as a protective measure. However, the intrinsic need for protective immobilization may be so great that powerful involuntary lumbar spasm develops to splint the lower back, to a varying degree decreasing or offsetting the attitude of flexion.

In my experience manipulation has played an important role in giving ease to the patient, decreasing the postural deformity, facilitating the use of other modalities (brace, corset, flexion bed, flexion cast) and shortening the period of invalidism.

TECHNIC.—The technic I employ is best accomplished after some preliminary form of heat to the lower back, but with the patient's cooperation manipulation may be performed without delay. The patient is placed on a therapy table in a true lateral position. The under leg is kept extended, but the upper leg is allowed to fall forward in a natural bend at the knee, the toes hooking lightly behind the other ankle. The under arm is held at 90 degrees to the body. The patient is then allowed to incline forward, resting the head on the under arm. The manipulator stands behind the patient, places one hand broadly over the posterior and lateral crest of the ilium, and places the other hand on the anterolateral chest wall covering the lower ribs. Then slowly, gently and steadily, without jerking, the ilium is pushed away from the manipulator in the long axis of the femur, while the other hand acts as countertraction and balance against the chest wall. During this maneuver a series of snapping sounds on the affected side is frequently heard and felt; when the maneuver is repeated on the asymptomatic side the snapping is usually less pronounced or entirely absent. This difference has been observed so constantly (regardless of whether the well or the affected side is manipulated first) that I believe it is of clinical significance in confirming the side and site of the lesion.

At this point if the patient is asked to rise from the table and stand on the floor, several facts will be elicited in a large percentage of cases. First, the patient will state that he can move a bit more freely, that he

that the psychoneurotic patient soon tires of the imposed treatment and is willing to concede improvement. On the other hand, the patient with real organic distress observes definite benefit and is willing to continue treatment until relief becomes permanent.

LESIONS OF THE HIP JOINT

Osteoarthritis of the Hip.—In my experience with treatment of the arthritic hip by manipulation alone the results have been disappointing. Improvement, if any, was usually short lived unless traction therapy was instituted as routine after-care, thereby prolonging and enhancing the improvement. Because of this observation, traction therapy was tried without manipulation and the results were found to be quite satisfactory. This statement, however, must be qualified to the extent that severely disorganized joints, as in *malum coxae senilis*, did not respond well to any form of conservative treatment. Therefore, the cases should be selected, and obviously the less involved hips respond best to treatment. Yet in many cases of advanced osteoarthritis, when surgery was contra-indicated, a modicum of relief could be obtained by traction.

TECHNIC.—The patient is placed supine on the therapy table, and traction is applied to the affected limb by means of a leather anklet. The foot of the table may be elevated to increase countertraction, especially with patients of light weight. Traction weight is transmitted over a pulley at the foot of the table; a pull of 10 pounds is applied at first, increased with successive treatments to 35 pounds, as tolerated. With active traction in effect, the therapist then supervises the routine application of short-wave diathermy, infra-red over a moist compress and deep massage to the affected hip region.

At the conclusion of traction and physical therapy, the hip is put through a session of stretching, in which an attempt is made to reproduce all of the usual components of hip joint motion. Of necessity, these maneuvers are limited and gentle in the beginning, but become more forceful at successive visits.

The principles underlying this technic are identical with those discussed in the section on cervical arthritis. Here, too, the patient should be warned that the first few treatments may aggravate the symptoms, but improvement is noted shortly thereafter.

If the patient is hospitalized, treatment may be given daily. When the patient returns to bed, traction is applied to the anklet and worn as constantly as possible, day and night. By means of a two-plane suspended splint the patient is able to work the hip into flexion as well as swing it into adduction and abduction. The apparatus is essentially the same as that used to mobilize the hip after arthroplasty.

If the lesion is mild (or the patient's circumstances must be considered economically or otherwise), the patient may be treated as an outpatient three times weekly. A simple direct traction apparatus is set up on the patient's bed and is worn at night to supplement the treatment received at the hospital.

It should be understood that the routines described are not infallible, but they will have served their purpose as motion is improved and/or pain is alleviated

CASE III—H J, white man, aged 64, was first seen on September 28, 1947, confined to his bed because of backache and pain in the right leg. For about twelve years, he had been subject to recurrent mild backaches, however, three years before the current illness he had had a severe attack of backache requiring one week's bed rest for relief. The most recent attack, three weeks earlier, had a

Patrick test performed on this leg was markedly positive, all other leg tests, including Lasègue, were negative. Raising the left leg, however, produced pain in the right sacroiliac region. The hip showed a 20 degree flexion contracture, internal and external rotation were each limited to about 5 degrees, abduction was limited to 20 degrees.

of the acetabulum

Diagnosis—Osteoarthritis of the lumbar spine and right hip joint

Course—During the acute phase the patient was unable to move from his bed, so traction was set up at home, and three physical therapy treatments were given each week. The patient was out of bed after seven days under limited activity. By the end of the third week spasm was notably decreased, motion was moderately limited in all components, being more limited in abduction; pain, however, was completely relieved. Examination one year later showed no further loss of motion, pain had not recurred, and the patient's activity was normal.

Slipped Femoral Epiphysis.—A great deal of controversy surrounds the question of treatment of femoral epiphyseolysis, but I believe that one facet of therapy in these cases falls within the field of manipulative surgery. A very rigid choice of cases must be made, the criteria for selection being:

1. A definite history of trauma should be obtainable
2. The slipping must be of very recent origin, not over three weeks' duration
3. The slipping must be less than 1.5 cm, as measured in the roentgenogram.

TECHNIC—Under general anesthesia the general principles of the Leadbetter maneuver are followed. With the patient supine and the pelvis fixed to the table, manual traction is applied to the affected limb in extension. Maintaining traction, the knee and hip are flexed slowly and gently to right angles. Next, the hip is rotated internally (still maintaining longitudinal or upward traction) and finally brought downward and outward into simultaneous extension and abduction.

The manipulation must be of the gentlest order. If x-ray control indi-

cates a failure of reduction, manipulation should be abandoned; repetition may do irreparable harm to the epiphyseal line and to the head of the femur. If the cases are selected wisely a good reduction is usually possible. The type of fixation of the hip after reduction rests with the surgeon and will not be discussed here, to prevent further complication of an already controversial subject.

DISABILITY OF THE KNEE

Manipulation of the knee is performed for reduction of a dislocated or torn semilunar cartilage, and for restoration of motion when limitation is due to post-traumatic fibrosis and/or osteoarthritis.

Meniscus Syndrome.—In cases of fresh dislocation of a semilunar cartilage reduction can be obtained in most cases by manipulation. In order to insure relaxation the manipulation may be facilitated by injection of several cubic centimeters of 1 per cent procaine at the point of maximum tenderness, or general anesthesia (pentothal sodium intravenously).

TECHNIC. The patient lies supine on the therapy table and the affected knee is brought into full flexion on the flexed thigh. Assuming that the medial meniscus is displaced, the operator externally rotates the tibia on the femur and at the same time exerts an abductory pressure against the knee (to increase valgus, open the medial joint space). Continuing to exert pressure in external rotation and abduction at the knee, the leg is then slowly extended to 130–140 degrees. At this point the foot and leg are vigorously derotated into full internal rotation, and by the same motion the knee is fully extended. When the lateral meniscus is displaced a corresponding technic is employed, except that the leg is internally rotated and adducted at the knee (crossed-knee position) and in the final phase derotated into external rotation while the knee is being extended.

In stubborn cases Fisher¹ uses an alternate method. The patient's knee is flexed over the end of a table at an angle of about 20 degrees. The operator grips the lower part of the patient's leg between his thighs, and then grasps the head of the tibia with his hands. Next, he uses the thigh grip to open up the inner side of the joint, at the same time forcibly moving the head of the tibia alternately and "rocking" the knee between adduction and abduction.

Fibrosis of the Knee Joint.—When the knee joint motion is limited after prolonged immobilization of the knee in extension after arthrotomy, or after fractures in or about the knee, manipulation may be of great benefit. Its use in arthritis—atrophy or hypertrophy—is very limited; however, in traumatic arthritis, the results are usually quite gratifying.

TECHNIC.—Under general anesthesia the patient is placed supine on a table and then drawn toward the foot until the well leg clears the table and drops at a right angle. The thigh of the stiff knee is held down firmly against the table by an assistant, while the operator stands at the foot of the table, places one hand over the patella and with the other hand grasps the leg firmly just below the level of the tibial tubercle. It is im-

portant to avoid gripping the leg too far distally, as this increases the leverage and the danger of producing a rupture of tendon or ligament or a fracture of the atrophic porotic bone of the patella, of the distal portion of the femur or of the proximal portion of the tibia.

The manipulator forces the tibia down into flexion by a steady, even pressure until the tearing of the adhesions is heard and felt as they rupture. *The leg must not be raised and lowered like a pump handle.* However, as more flexion is obtained, the operator may judiciously increase the lever arm of his grip. This sense of balanced force is acquired only with experience, and if the manipulator is in doubt as to how much force he should employ he would do well to accept a small gain in motion and repeat the procedure later after the acute reaction of manipulation has disappeared. There is no contraindication to repeated manipulations as long as each manipulation results in an appreciable gain of motion in the joint.

LESIONS OF THE FOOT AND ANKLE

The closely knit relations of the ankle mortise the relative weakness of the fibular collateral ligament, and the complex integration of the bones of the foot make these joints particularly unsuited for manipulation when arthritis of any notable degree has developed. In fact, mobilization of these arthritic joints may produce more pain on weight bearing and increase the disability.

However if stiffness which is the result of trauma (without x-ray evidence of joint damage) is unduly slow in responding to the usual modalities of physical therapy and exercise, manipulation may occasionally prove beneficial. However, a fair trial of physical therapy is first indicated.

TECHNIC.—One hand grasps the heel firmly from below and exerts strong traction while the other hand, successively, guides the posterior foot into inversion, eversion, plantar flexion and dorsal extension. Shifting the grip somewhat distally to grasp the astragalus, the forefoot is successively twisted into supination, pronation, abduction and adduction.

SUMMARY AND COMMENTS

The practical clinical application of manipulative surgery to the field of orthopedics has been reviewed. The text has departed to some extent from the orthodox form of presentation, and the intent has been to present useful information about the most common lesions seen in practice, rather than to be encyclopedic. The techniques described are those which have proved the most helpful in the most cases.

In a number of conditions my evaluation of methods and results has been at variance with those reported in the literature, but my evaluation is based on personal observations, frankly reported, and is not a compilation of medical writings. A plea has been made for accuracy in estab-

lishing diagnosis and indicating sound treatment. Conservatism in therapy has been stressed, with full recognition of both the physical and the psychological status of the patient.

Finally, the need for greater recognition by the medical profession of the usefulness of manipulative therapy in general and specialized practice has been emphasized. This recognition must come from within the ranks of the profession itself, starting in the curricula of the medical schools. The acceptance and practice of good manipulative surgery will have three beneficial consequences:

1. A valuable modality will be added to the armamentarium of the practicing physician.
2. The general public will be better served by virtue of this increment to medical knowledge.
3. The sound practice of manipulative surgery will serve to alienate the patients from the services of the irregular practitioners of medicine, and return them to the fold of trustworthy medical practice.

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CHONDROMALACIA PATELLAE

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ETIOLOGY

THE term "chondromalacia patellae" was first used in the literature by König (1924). It applies to a circumscribed degeneration of the patella, as evidenced by softening, fibrillation with eventual fissuring and erosion of the cartilage. Direct injury and loss of nutrition produces the pathologic changes in the cartilage of the patella.

After a careful review of the literature, Bronitsky summarized the present trend of thought regarding the etiology, as follows:

1. Our knowledge of the physiology and nourishment of cartilage is still incomplete.

2. Degeneration of cartilage without trauma does not exist.

3. Acute trauma or static deformities can influence the origin and progress of the disease.

4. The question of constitutional disposition and heredity as etiologic factors is still unsettled.

The incidence of chondromalacia of the patella as determined by arthrotomies varied with different investigators. Aleman (1927) reported that one third of the 200 arthrotomies on soldiers in the third decade of life revealed a focus of softening and fissuring of the patellar cartilage. Hilzensauer (1936) found forty-eight cases in 1000 arthrotomies. Chaklin (1939) found thirty-eight chondromalacic patellae in 159 operations on the knee. Anderson (1944) at a Naval Hospital reported ten out of fifty successive arthrotomies showed changes in the patella. Soto-Hall (1945) at an Army Hospital found twelve instances in sixty-five arthrotomies performed for chronic knee complaints. Darrach (1939) noted that in 376 arthrotomies 6.8 per cent revealed degenerative changes in the patella as the only demonstrable pathologic change found in the knee. Cave, Rowe and Yee (1945) reported 124 arthrotomies with nine instances in which the patellar cartilage degeneration was the only cause for symptoms.

The youngest patient reported as having chondromalacia patellae was 10 years of age. The youngest patient with the disease verified at operation was 13 years of age.

In an autopsy report by Owre (1936) of knees examined in which there were no complaints referable to the joint, it was found that de-

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generation of the patella existed as follows.

Years of Age	Incidence
1-19	5 out of 18 and all over 14 years of age
20-29	27 out of 32
30-39	24 out of 26
40-59	30 out of 32
60-80	all 16 cases

It was also noted that the degree of severity of involvement increased with age.

The patella begins to show early degenerative changes on the medial aspect with the central and lateral areas less frequently involved. In severe cases and those with late changes, the entire surface of the patella is involved.

Wiberg made a study of the anatomy of the patellofemoral joint. He showed that in 20 to 50 degrees flexion, the lateral facet and a small part of the medial facet contacted the articular surface of the femoral condyle and the greatest stress was on the central longitudinal ridge.

With increased flexion of the knee, the pressure on the ridge diminishes and at 90 degrees it disappears completely. At this point the patella reaches the intercondylar notch, and contact is maintained by the larger lateral and smaller medial facets. During flexion, the lateral patellar facet continues in good congruence with the lateral femoral condyle, while the medial facet of the patella, from an angle of 90 degrees and upward, opposes a convex surface to the convex femoral condyle.

DIAGNOSIS

The diagnosis is based upon a history of chronic knee discomfort of varying degrees of severity. Pain in the medial front portion of the knee is accompanied by weakness and a tendency of the knee to buckle, or give way. These symptoms are aggravated or first noticed when climbing a hill or walking up and down stairs. Pain may be present in the anterior thigh and anterior lateral leg. The thigh pain is due to reflex spasm or fatigue of the quadriceps mechanism. The lateral leg pain may also be on a muscle fatigue basis because the patient attempts to splint the knee in flexion when walking. The mechanics of walking with the knee flexed can produce the thigh and leg pains. Quite frequently this necessitates a differential diagnosis of radiating pain in the lower extremity. Many patients are erroneously considered to be suffering from some form of "sciatica" or circulatory disease.

Repeated momentary lockings of the knee occur resulting in loss of full . . .
pa . . .

like tags or loose bodies break away from the articular surface of the patella.

The knee frequently aches after remaining in one position for a while.

After assuming activity following a short period of rest, the knees were held in flexion, there is much discomfort. The history of morning tightness of the joint, with the same feeling after walking, is indicative of an advanced case of osteoarthritic changes.

Crepitation of the patellofemoral joint is the most diagnostic sign of this disease. The patella must be moved over the femoral condyles and moved up and down in order to elicit the subpatellar crepitus. It is present under the patella and varies from a single click or soft velvet-like sensation, to a creaking, crunching, grating sound, which is heard at a distance of several feet. Crepitus indicates degeneration of the cartilage. The absence of crepitation does not rule out degeneration of the cartilage.

The crepitation is often only obtained when the knee is activated while the examiner palpates the joint.

Pain on pressure applied to the patella is often present. The patella must forcibly contact either femoral condyle in order to elicit the pain. The medial femoral condyle in complete extension is reduced. It is a dull aching pain becoming acute when the patella is forced against the femoral condyle.

The synovial membrane may be thickened and the patellar fatty tissue edematous. There may be effusion when pain and effusion has been present for some time.

At the time of arthrotomy, the joint fluid will be found floating pieces of cartilage will be found.

The patella will reveal early findings in the early stages. The change from the normal bluish white shiny surface to one of a yellowish, opaque and soft degenerated surface. The surface appears with fraying of the cartilage and the surface tags. As the cartilage is gradually ground down, the surface becomes exposed. The exposed bone eventually becomes eburnated. All or a portion of the articular surface becomes eburnated. Marginal osteophytes appear early and the surface becomes irritated. The contiguous portions of the femoral condyle show erosion but seldom fibrillation. The microscopic lesions are those of fibrillation of the superficial layer of the cartilage. Swelling of the deeper adjacent layer and the presence of cells. The individual cells degenerate, increase in size and are grouped together in small groups. As the clefts and fissures appear, the clusters appear in the vicinity. The thickness of the cartilage is reduced. The subchondral bone shows degenerative changes. The articular cartilage has become markedly altered.

When the erosion extends for a distance in the marrow of the subchondral bone, there is proliferation; fibrous tongues often appear. In close proximity to this new

mentous
us.



S. Open knee lateral view re- with cartilage with large lower



al diagnosis.
chondro-ossseous
D. Clinical diag-
or pole osteopor-
knee

found cartilage and bone. Occasionally an isolated mass of cartilage will be found in the narrow spaces of the subchondral bone

Röntgenograms are of no value in the early stages. Osteophyte formation will verify the presence of degeneration of the articular cartilage

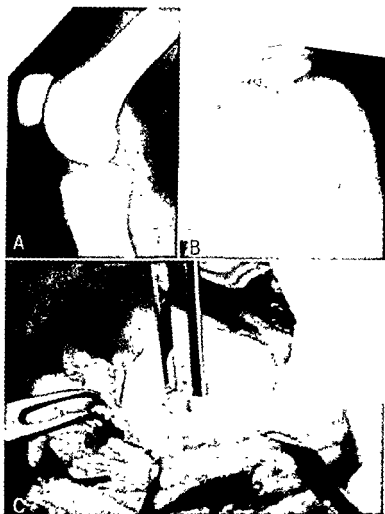


Fig. 112 (Patient W. F.)—Clinical diagnosis of chondromalacia. A, Lateral view reveals lower patellar pole osteoporosis. B, Tangential view—no diagnostic findings (See also Figure 114, A.) C, Tissue forceps probing into degenerated cartilage with spreading of fibrillations revealing defect.

Special tangential or "skyline" views of the patella may reveal slight changes of the subchondral bone. There are often osseous flakes or chips lying on the articular surface of the patella. Indentations of the patellar cartilage may be present but relationship to chondromalacia patellae is debatable. Even pneumography will be of limited value. The roentgenogram may be important only because of negative findings.

A differential diagnosis includes other causes of internal derangement

of the knee joint such as meniscus lesions, loose bodies, ligamentous instability, fat pad pinchings, synovial adhesions and plica tears.

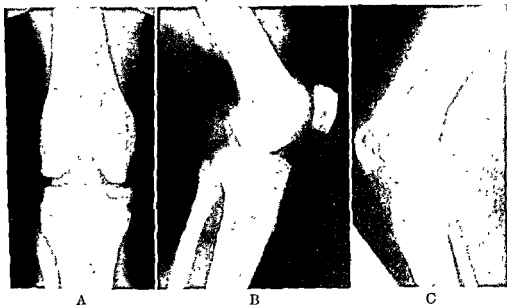


Fig 113.—Clinical diagnoses of chondromalacia. *A*, Patient R. S. Open knee view of patella reveals lower pole osteoporosis. *B*, Patient A. S. Lateral view reveals lower pole osteoporosis and indentation at central portion with cartilage flake. *C*, Patient P. D. *B*. Lateral view reveals joint osteoarthritis with large lower pole osteophyte.

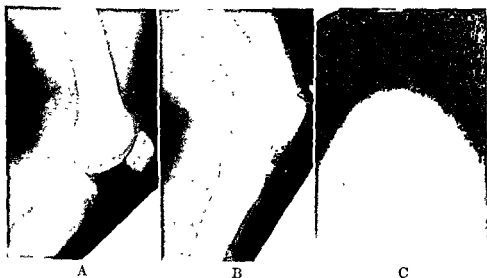


Fig 114.—*A*, Patient J. F. Arthrotomy diagnosis confirmed clinical diagnosis. Lateral view reveals lower pole osteoporosis and osteophyte or chondro-osseous flake (For patellar photograph see Figure 112. *C*.) *B*, Patient L. D. Clinical diagnosis of chondromalacia. Lateral view reveals superior and inferior pole osteoporosis and osteophytes. *C*, Same patient. Tangential view of right knee reveals subchondral osteoporosis of the lateral border and large chondro-osseous defect in medial border with small loose body in patellar bed.

According to Soto-Hall, the diagnosis must rest on combinations of the following signs and symptoms: (1) subpatellar crepitation on active

movement; (2) variable deep-seated pain; (3) tenderness on percussion of the patella; (4) a pseudo-locking, or ratchet rhythm; (5) a subjective feeling of instability; and (6) occasional recurrent subluxations of the patella.

TREATMENT

Conservative management of early cases consists of minimizing joint trauma, quadriceps active exercises with resistance and physical therapy. In the advanced cases where the symptoms are chronically disabling, arthrotomy and surgical correction is indicated.

Types of Operations.—Surgical procedures advocated for the relief of symptoms of chondromalacia patellae are as follows:

1. Resection of patellar cartilage referred to as *chondrectomy*. The degenerated fibrillated cartilage is shaved smooth by a sharp scalpel blade. The underlying bone is not exposed but most often the shaving is carried down to the surface of the osseous portion of the patella.

The patellar articular surface can then be covered with synovia or other interposing substance such as oxycel or gel foam. The synovial covering did not yield as good results as oxycel but it has become evident that interposition is definitely a hindrance to recovery in chondrectomy. The results are best if no covering is used in the cartilage resection operation. The operation of chondrectomy is used when the pathological changes are early and the underlying bone is not involved.

2. *Patellaplasty* or total resection of the articular cartilage in which the entire patella with the exception of a bony shell is removed. This operation is used in moderately advanced cases. The raw bone surface of the patella is covered with synovia, fascia or oxycel. This yields only fair results and is being discarded in favor of patellectomy. The surgical approach is through a medial parapatellar incision. The patella is rotated through an arch of 180 degrees on its long axis to expose the cartilage surface.

3. *Patellectomy* is the procedure of choice for all stages of chondromalacia patellae with the exception of the very early lesion as found chiefly in the adolescent or young adult. The decision lies between chondrectomy and patellectomy as the operative method. We feel that when the subchondral layer is intact, a chondrectomy will suffice.

The patella normally lies behind the quadriceps tendon aponeurosis which helps to form the capsule of the knee joint. Good function of the extensor mechanism and knee joint can be obtained after total excision of the patella. Brooke proved this in patellectomy for fractures.

Patellectomy can be considered as a specific treatment for chondromalacia patellae. It eliminates the mechanical impediment to function due to degenerative changes in the patellar femoral joint.

Preoperative Preparation.—This consists of quadriceps exercises and instruction of the patient concerning the importance of good extensor muscle control. Within forty-eight hours following patellectomy, the

patient is encouraged to contract the quadriceps as a frequent exercise. After two weeks, straight leg lifting exercises are performed and resistive exercises are added.

Technic of Operation.—The technic of the operation consists of a saucer-shaped horizontal incision with convex edge crossing the inferior pole of the patella. The quadriceps expansion is incised in line of the skin incision and the lower end of the patella is dissected free from the patellar tendon. By sharp dissection the patella is separated from the quadriceps expansion.

The proximal flap of the quadriceps expansion and quadriceps tendon is sutured to the distal flap of the quadriceps expansion and patellar tendon in a transverse manner. The flaps and tendons are overlapped about $\frac{1}{2}$ to $\frac{3}{4}$ inch. The suture material can be fascia lata but silk or cotton has been found adequate.

The postoperative dressing for the knee is a compression elastic bandage. A posterior plaster splint which remains on for ten days or traction can be applied to maintain postoperative extension of the joint.

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THE INDICATIONS AND TECHNIC OF FOOT STABILIZATION IN INFANTILE PARALYSIS

ROBERT O. RITTER, M.D.*

DEFORMITY of the foot, with or without instability, following an attack of infantile paralysis is a serious handicap to walking. Attempts to correct these deformities by conservative manipulations, tendon transplantations, casts or braces have never proved entirely satisfactory.

It was not until the relationship of the various joints of the foot to the deformity was recognized that the limitations of conservative treatment were overcome by rational surgery.

After all return of muscle power has ceased, and the patient has reached the age of 7 years or more, arthrodesing operations may be done without too much bone destruction. Arthrodesing operations on the foot are not indicated on very young children no matter how long since the attack. So much cartilage and bone would have to be destroyed that the growth of the foot would be seriously retarded. Until such time as the patient reaches the age at which an arthrodesis can be done with the least amount of cartilage and bone destruction, conservative measures must certainly be followed.

An arthrodesis is a useful operation for foot stabilization when properly done. This means adequate incisions, properly placed, careful removal of cartilage and bone, backward displacement of the foot, and good apposition of bone, with the foot in neutral lateral position. Poor results are due to poor bone apposition, failure to immobilize the foot in the proper position, and maintenance of immobilization for too short a period of time.

In planning an operation on a paralytic foot the surgeon should thoroughly study the foot to determine the forces causing the deformity, what to do to correct it and to prevent its recurrence. He should also plan the incision, or incisions, that will best expose the area to be operated. The majority of foot deformities, such as equinovarus, calcaneovarus or valgus, are the result of muscle imbalance. The flail drop foot results from a complete loss of power in the leg muscles. It is obvious, therefore, that no one incision or one type of operation is suitable for all foot deformities. The aim of surgery on a deformed foot is to relieve pain, restore as nearly as possible its normal function, namely, support and transportation of body weight. Further, the aim of surgery is to restore a more normal appearance of the foot and to allow braces to be discarded.

The first real attempt in this country to fuse the subastragaloid joints was that of Davis in 1913.¹ He destroyed the joint between the astragalus and the os calcis and the astragaloscaphoid joint by thoroughly

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gouging up the cartilage and bone but not removing any of the chips from the wound.

Dunn,² in 1919, described his operation for calcaneo cavus deformity. Through one long incision extending from just above and in front of the external malleolus to the dorsal surface of the base of the fifth metatarsal bone, all the joints of the tarsal bones were exposed. The head of the astragalus, the scaphoid, and the cartilage from the cuneiform bones were removed. A block of bone and articular cartilage was removed from between the os calcis and the cuboid. The ligament between the astragalus and os calcis was divided and the cartilage removed from the adjacent surfaces of these bones. The foot was then displaced backward at this joint and the astragalus fitted snugly into the cuneiform bones. The raw surfaces of the os calcis and the cuboid were also opposed. Following closure of the operative wound a plaster cast was applied from the toes to the knee.

In 1921 Hoke³ described an arthrodesing operation which he performed on children as young as 6 years. He removed all soft tissue from the subastragalar fossa, divided the astragaloscaphoid ligament, and removed the inferior articular surface of the astragalus and the adjacent articular surface of the os calcis. Next, he amputated the head and neck of the astragalus at the junction of the neck with the body. The removal of the cartilaginous facet from the upper surface of the os calcis allowed the foot to be displaced backward. The head and neck of the astragalus were then trimmed down and replaced between the body of the astragalus and the scaphoid; the foot was cocked up to the desired position and held while the wound was sutured and the plaster cast applied.

Hibbs⁴ devised an operation based on the facts that the astragalus is the most stable bone in the foot and that the deformities occur in the mid-tarsal and subastragalar joints. Through two incisions long enough to expose completely the involved joints, all cartilage was removed from between the astragalus and os calcis, and from between the astragalus and scaphoid. Enough bone was removed from between the cuboid and os calcis and from the astragaloscaphoid joint to allow sufficient backward displacement of the foot with all raw bone surfaces in close contact. The foot was fixed in plaster in the neutral position until solid fusion occurred.

In 1923 E. W. Ryerson⁵ described his triple arthrodesis for paralytic feet. This is the operative procedure the writer has followed and used in most instances, and which has given eminently satisfactory results.

TECHNIC OF ARTHRODESIS

Through two incisions, one on either side of the foot, the tarsal joints are exposed (Fig. 115). The capsules and ligaments, including a thin layer of bone, are laid back from each side with a thin, sharp osteotome, thus exposing the joints to be arthrodesed. The cartilage, with the necessary amount of bone, is then removed from between the astragalus and the os calcis from the astragaloscaphoid joint and the calcaneocuboid

joint (Fig. 116). If need be, the cuneiform joints and the joint between the internal cuneiform and the first metatarsal can be fused. In extreme

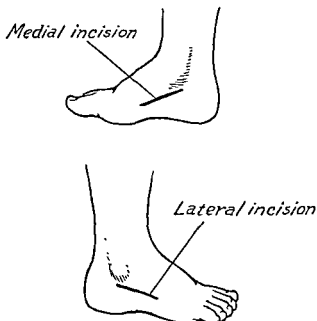


Fig. 115.—Incisions for exposure of the tarsal joints.

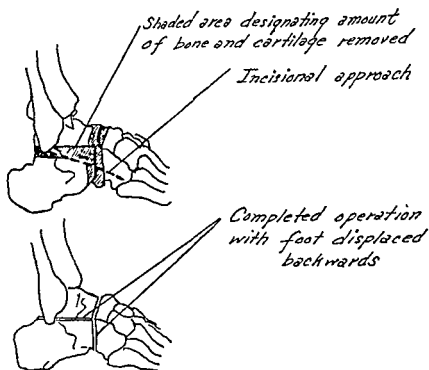


Fig. 116 —Showing amount of bone and cartilage to be removed for the backward displacement of the foot.

cavus deformity the entire scaphoid and head of the astragalus are removed. When the foot is displaced backward, the joint spaces are so

changed that when the layers of bone and capsule are replaced the bone acts as a graft across the arthrodosed areas. With a strong spear-pointed needle these layers are sutured in place with interrupted No. 1 chromic catgut sutures. The subcutaneous tissues are closed with interrupted plain catgut and the skin closed with interrupted silk sutures.

In many cases the anterior tibial and also the posterior tibial muscles are paralyzed while the peroneus muscles remain strong and active. In such a case the peroneus longus tendon should be transplanted so that it may act as a dorsiflexor of the foot. The tendon is divided through the original incision at the point where it passes under the foot. It is extracted from its sheath through an incision higher up on the leg (Fig. 117). The tendon is wrapped in moist gauze while a tunnel to the inner side of the

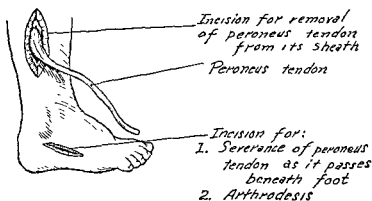


Fig. 117 — Incisions for removal of peroneus tendon and for arthrodesis

leg is made for it. Through the original incision on the inner side of the foot the tendon of the paralyzed anterior tibial is slit longitudinally over the internal cuneiform. Through this slit in the tendon a trap door is made in the internal cuneiform to receive the transplanted peroneus longus. An anchor suture of braided silk is placed in the peroneus tendon. Now, through a short incision, the anterior tibial tendon is exposed just above the annular ligament and a slit made in its sheath; the anchor suture in the peroneus tendon is threaded through the eyelet of a long flexible probe and the tendon pulled down the sheath of the anterior tibial and out at its insertion (Fig. 118). With a heavy spear-pointed needle one end of the anchor suture is passed through one side of the groove in the cuneiform, and the other end is passed through the opposite wall. The cut end of the peroneus tendon is then pulled into the groove, the trap door laid over the tendon and tied down by the anchor sutures. Two or more interrupted sutures are applied for firmer anchorage. Thus, the transplanted tendon has an insertion in bone (Fig. 119). It is important that the transplanted tendon pulls in as straight a line as possible, pulling around an angle lessens its efficiency. Care must be used in determining the tension of the transplanted tendon. If it is too slack some of

its power is lost; if under too much tension it cannot contract and it becomes, in time, a useless fibrous strand.

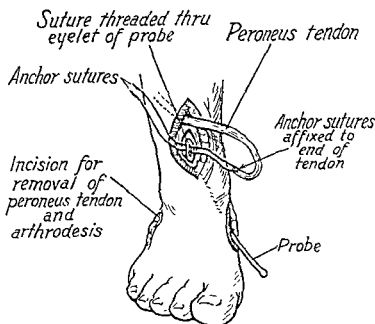


Fig. 118—Manner of threading anchor suture through eyelet of probe and pulling the peroneus tendon down the sheath of the anterior tibial and out at its insertion.

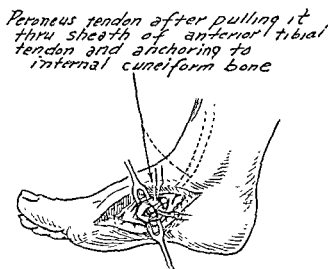


Fig. 119.—The transplanted tendon.

Where the calf muscles are paralyzed and the peronei and anterior and posterior tibial are functioning, the peronei or the posterior tibial or both can be transplanted into the tendon of Achilles and the os calcis.

While the foot is held in the desired position all incisions are closed with interrupted sutures. The incisions are covered with narrow gauze dressings moistened with alcohol. The dressings should not overlap in

front of the ankle, as they produce a constriction band when the foot swells. Sterile stockinette is rolled over the foot and leg and padded with sterile sheet wadding. With the knee flexed, a plaster cast is applied from the toes to the mid-thigh. After the operation, the foot is held in an elevated position until it becomes painless. The cast is split over the dorsal surface of the foot and well up the leg; the entire dorsal surface of the toes is exposed so that they may be inspected often for circulatory changes. If there is interference with circulation a strip must be cut the full length of the cast and the skin inspected to make sure the dressings are not constricting the ankle and leg.

An arthrodesis is a painful operation and the patient must have enough sedation to insure rest and sleep for the first two or three days following the postoperative day. Immobilization in a plaster cast must be maintained for a period of twelve weeks without weight bearing. Following removal of the cast an elastic bandage should be worn until the circulation becomes readjusted.

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PHALANGECTOMY FOR TOE DEFORMITIES

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SIDNEY SIDEMAN, M.D.‡

WE wish to draw attention to a simple operative procedure for the treatment of painful disabling deformities of the toes. This operation has been found useful in a multiplicity of conditions including hammer toes, overriding toes, corns and the severely contracted toes which may occur in rheumatoid arthritis and in the chronic stage of poliomyelitis.

This procedure was brought to our attention during World War II on examining a German prisoner of war, for whom the proximal phalanx had been removed for the treatment of hammer toe; the functional and cosmetic result was excellent. It seemed apparent that this operation was preferable to the numerous procedures currently in use and that it could also be applied in the correction of many other deformities of the toes.

In a search of the literature, the earliest mention of this procedure that we could find was in 1924 when Engel¹ recommended partial phalangeotomy for the treatment of claw of the small toe and stated that the entire proximal phalanx could be removed if it was desired to provide considerable space. Tretlow² in 1925 stated that proximal phalangeotomy had been considered for the treatment of hallux valgus but advised against this procedure because it would shorten the great toe excessively; but Schantz³ in 1929 reported that he had been removing the proximal phalanx of the great toe according to Witzel's suggestion. Manwaring⁴ in 1930 stated: "Realizing that toes are of little use, we do not hesitate to 'bone' some of them." Dr. Joseph A. Freiberg⁵ of Cincinnati, Ohio informs us in a personal communication that his father, Dr. Albert Freiberg, for many years performed proximal phalangeotomy of the fifth toe for dorsiflexion deformity.

The operative technic is simple. The base of the proximal phalanx is exposed and dissected out through a short dorsal longitudinal incision placed well proximally. The phalanx is grasped with a towel clip and delivered externally. The remainder of the phalanx is then stripped subperiosteally and is removed. The toe assumes a natural position and is easily held with a simple dressing and bandage.

We have operated on twenty-one patients and have performed a total of fifty-four phalangeotomies varying from a single toe to eight toes at one operation.

We do not recommend this procedure on the great toe and have not used it in any pathological condition of the great toe.

The following advantages of this operation are noted: (1) its simplic-

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ity; (2) rapid convalescence; (3) early ambulation; (4) excellent cosmetic appearance, (5) relief of cutaneous pressure keratosis by removal of underlying bone. Finally, (6) correction of a deformity by generous removal of bone results in adequate relaxation of contracted tendinous and ligamentous structures, and (7) absence of raw bony surfaces insures against ankylosis of the toe.

It has been interesting to observe that these toes do not remain flail, and active functional control is restored early.

This operation is especially applicable to the crippling toe deformities of rheumatoid arthritis for which the mutilating Hoffman operation was performed in the past with such disappointing results. We have had three patients of this type for whom we have performed phalangectomies

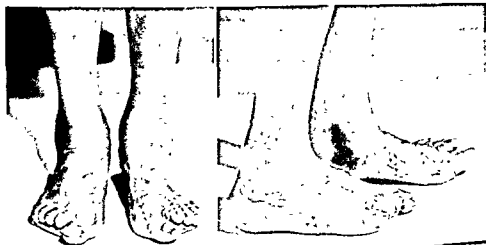


Fig. 121 (Patient K. D.).—Severe arthritis deformans, both feet, following phalangectomies (front).

of the second to the fifth toes inclusive combined with a Keller operation on the great toe. The results have been most gratifying.

We have recently performed a proximal phalangectomy for a tender swelling of a second toe due to a large enchondroma.

ILLUSTRATIVE CASES

Rheumatoid Arthritis.—Figure 120, *upper*, shows roentgenogram of the left foot of a patient who had contractures of all the toes on both feet and was unable to walk because of pain over the metatarsal heads and toes. Bilateral multiple phalangectomies were performed. Figure 120, *lower*, shows the left foot postoperatively. This patient became ambulatory three weeks after her operation. She wears shoes and walks with little discomfort.

Figure 121 shows the cosmetic appearance of both feet following multiple phalangectomies for toe contractures resulting from rheumatoid arthritis in another patient.

Hammer Toes.—Figure 122, *upper*, illustrates a second hammer t

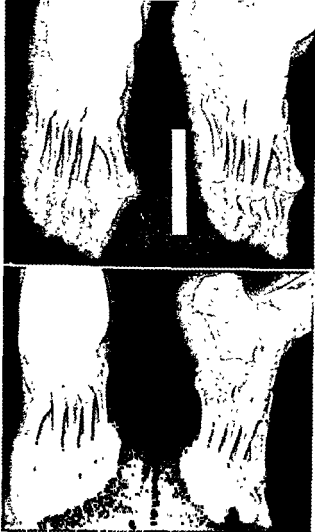


Fig. 122 (Patient J. C.).—Upper, Preoperative x-rays. Diagnosis: bunion; dislocation of interphalangeal joint. Lower, Postoperative x-rays. Phalangeectomy of second toe. Result: good.



Fig. 123 (Patient R. C.).—Postoperative x-rays of bilateral dorsiflexion deformities of fifth toes.

associated with a hallux valgus. The postoperative roentgenographic appearance is seen on Figure 122, lower. This operation may sometimes

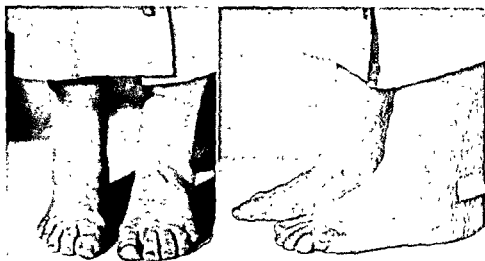


Fig 124 (Patient B. D.).—Dorsiflexion deformities of fifth toes resulting from chronic poliomyelitis with residual paralysis.



Fig. 125 (Patient L. M.).—Postoperative x-rays of congenital overriding of fifth toe.

be performed for a normal second toe which becomes excessively long after a Keller bunionectomy.

Congenital Overriding and Dorsiflexion Contractures of the Fifth Toe.—Figure 123 shows operative correction of dorsiflexion contractures

of the fifth toes. Figure 124 shows the postoperative appearance in a bilateral case. Figure 125 reveals a postoperative case in which there was congenital overriding of the fifth toes.

In the fifth toe, there may be some persistent flailness after phalangectomy, but this has not been sufficient to prove troublesome.

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PEDIATRIC ORTHOPEDIC SURGERY

CHARLES N. PEASE, M.D., F.A.C.S.*

THE assignment of the above subject is a large one and obviously only a few cases can be discussed in the space allotted. The following, however, are a few conditions which are not infrequently seen in a children's orthopedic clinic.

SLIPPING OR DISLOCATING PATELLAE

C. S., a girl aged 10, was admitted to the hospital in March 1943 at which time the history disclosed that during the preceding year the child had fallen several times as a result of a dislocation of one or both of the patellae

There is no alternative in the management of this condition. Treatment is surgical but transference of the tibial tubercle to the medial side of the tibial shaft advised by Wolf, Walsham and Goldthwaite in 1904 is ill advised because this almost always produces an arrest of growth of the tibial epiphysis.

A description of the procedure used in this case is as follows: Through a medial parapatellar incision (Fig. 126), the patella, quadriceps tendon and patellar ligament were isolated. It was noted that fibers from the tensor fasciae latae were inserted into the lateral portion of the insertion of the quadriceps tendon and into the lateral border of the patella. This anomalous insertion of the fascia lata may be an underlying factor accounting for the lateral displacement of the patella (Fig. 126).

The fibers of the tensor fasciae latae were divided at the point of its insertion into the quadriceps tendon and the patella. Likewise the insertion of the vastus lateralis was divided.

The quadriceps tendon, patella and patellar ligament were isolated on their lateral aspects with the incision extending through the capsule of the knee joint. The patellar ligament was divided at its point of insertion into the tibial tubercle. A recess was made on the medial aspect of the shaft of the tibia by making 1-inch parallel transverse cuts $\frac{1}{2}$ inch apart through the periosteum and cortex. An osteotome was inserted subcortically connecting the parallel incisions thus making a slot for the reception of the patellar ligament which was then passed through and fixed with interrupted silk sutures.

The aponeurotic tendon of the vastus medialis was divided along with the redundant medial portion of the knee joint capsule.

The redundant capsule on the medial aspect of the knee joint which had been divided was imbricated using No. 00 chromic catgut. The tendon of the vastus medialis was sutured to the medial aspect of the patella and to the medial collateral patellar ligament with interrupted

From The Children's Memorial Hospital, Chicago

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silk sutures (Fig. 127). Following skin closure, a long leg cast was applied which was removed at the end of four weeks.

A most satisfactory result was obtained in establishing stability at the knee joints (Fig. 128).

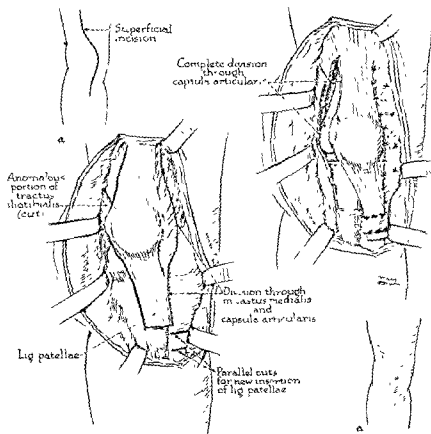


Fig. 126

Fig. 127

Fig. 126 —Drawing showing lateral displacement of patella with insertion of fibers of tensor fascia lata into its lateral border.

Fig. 127 —All structures on lateral aspect of quadriceps tendon, patella and patellar ligament are divided. Patellar tendon transplanted to medial aspect of shaft of tibia. Redundant soft tissues on medial aspect of knee divided and respective layers imbricated.

SOLITARY BONE CYSTS

This case is one in which localized cystic disease of bone can be quite definitely traced to acute infection.

D. Mc., a 6 year old boy, was seen in March 1937. Four years previously this child had suffered from an acute abscess on the lateral aspect of the lower end of the right thigh just above the knee joint. Incision and drainage was accomplished by a local surgeon but no cultures were made of the material. After three months of drainage complete healing took place. About eighteen months later there was

a recurrence of the abscess at the same site which drained for six weeks before healing. X-ray films were then made for the first time and the diagnosis was made of "tuberculosis of the bone." The leg was placed in a series of casts over a two-year period.

Examination on admission revealed no swelling or areas of tenderness in the right thigh or about the knee joint. However, there was atrophy of the right lower



Fig 128 (Patient C. S.).—Upper, Girl, aged 10, with bilateral dislocation of patellae March 1943. Lower, Postoperative correction, January 1944

extremity obviously due to the two-year period of immobilization. Although the affected extremity was in a cast for two years the leg measured 1 inch longer than the left leg. The Mantoux test was negative.

X-ray films revealed a cystic area which measured 1 by 2 inches, located about 1 inch proximal to the distal femoral epiphyseal plate. The walls of the cyst were sclerotic. Extending from the epiphyseal cartilage into the cyst was a $\frac{1}{2}$ inch wide column of decreased density with sclerotic of its walls.

in a cast for two years, note the overgrowth due to foreign body reaction of the contents of the cyst (Fig. 129, *left*)

This boy was operated upon, a lateral incision being made over the site of the pathologic involvement. When the cortex of the femur was removed and the cyst exposed there appeared an encapsulated mass of yellow fibrous-fatty appearing tissue which was gelatinous in character. This material was removed, the walls of the cyst were freshened and chips taken from adjacent bone were packed into the cavity which resulted in complete obliteration of the cystic area (Fig. 129, *right*).

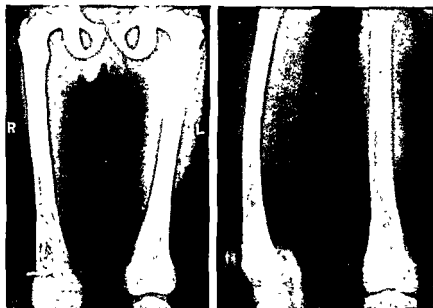


Fig. 129 —*Left*, Anteroposterior view of both femurs March 1937. Arrow shows rarefied column extending from epiphyseal plate to cyst. Note overgrowth of right femur. *Right*, Anteroposterior and lateral views of right femur January 1939 showing obliteration of cystic area by bone obtained locally.

Routine smears and cultures made from the specimen showed no growth for all organisms including the tubercle bacillus. Guinea pig inoculation also was negative. Sections of the contents of the cyst revealed no further information other than that which is seen in any chronic nonspecific localized infection.

This, no doubt, is a case of bone cyst resulting from localized infection originating in the epiphyseal cartilage of the femur which has "burned itself out."

lesions

The only treatment he received was protection of the right arm in sling for ten days.

X-ray films made three years later revealed a complete effacement of the cystic area (Fig. 130, *right*). Note the growth of this area away from the epiphyseal plate and the overgrowth of the humerus

Operation on this boy when first seen might have resulted disastrously since the cyst was adjacent to the epiphyseal plate and any surgical interference might have caused arrested growth.



Fig 130 (Patient M. C.).—*Left*, Fracture through solitary cyst of upper end of right humerus in a boy of 4 years. *Right*, Three years later showing complete effacement of cystic area without any surgical interference

PYOGENIC EPIPHYSITIS

R. M. K., female, was first seen on March 22, 1938 at the age of 4 weeks. The mother stated that when the child was 9 days old the left leg and knee joint were swollen and the leg held in position of flexion. About a week later the swelling became greater and a point of drainage appeared on the lateral side of the knee. Pus drained for ten days after which the swelling subsided.

This child has a complete range of motion at the left knee joint. The series of x-ray films shown are interesting as in very young children we have no reliable means to determine the extent of destruction of the epiphysis. The lateral condyle was retarded while the medial was stimulated in growth which produced a knock-knee (Fig. 131, *left*).

A supracondylar osteotomy was performed at the age of 4 to correct the valgus deformity of the left knee.

Note the gradual ossification of the lateral condyle of the femur which in the early films seemed to have been completely destroyed (Fig. 131, *right*).

OSTEOMYELITIS

Since the introduction of antibiotics osteomyelitis has been almost completely a medical problem. The pediatrician who often is the first to see a case of osteomyelitis in its very early stages usually administers

penicillin, sulfa drugs or both and in almost all cases no surgical intervention is necessary. The following case report illustrates this point very well

H W, a boy aged 10, was admitted to the hospital December 20, 1945 One week prior to admission the child experienced pain, redness and swelling of the lower right leg with an oral temperature of 104°F. Penicillin and sulfathiazole had been administered by the family physician

A consulting surgeon who saw this child recommended incision and drainage of a fluctuant area which formed over the lower third of the tibia The attending physician then asked me to take over treatment of this boy

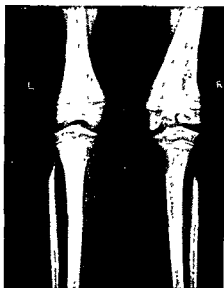


Fig. 1 (Continued from page 285) Left Showing what appears to be complete dislocation of the knee joint

Examination revealed redness and swelling of the lower half of the right leg There was a fluctuant area over the anterior surface of the tibia in its lower third Rectal temperature was 101°F, white blood corpuscle count was 13,700 with 69 per cent polymorphonuclears, 28 per cent lymphocytes and 3 per cent mononuclears

X-ray films made of the right leg in multiple planes showed no evidence of pathologic change

Sulfathiazole and sodium bicarbonate, 15 grains each, were given along with the administration of penicillin, 50,000 units, every three hours Temperature became normal after two days. When the patient became nauseated and vomited on the seventh day after admission the sulfathiazole was discontinued. Penicillin, however, was continued until the discharge date, January 14, 1946

The fluctuant area had diminished greatly but there was still enough fluid that it could be aspirated for examination.

The aspirated material was clear serosanguineous fluid. Cultures made from it revealed no bacterial growth.

Note new bone formation along the shaft of the tibia on films made January 8, 1946, four weeks after onset (Fig. 132, *left*).



Fig. 132 (Patient H. W.).—*Left*, Anteroposterior and lateral x-rays of right leg three weeks after onset. Note demineralization of lower end of tibia and periosteal reaction in lateral view. Films made four weeks later. Compared with distances from articular surface than on left.

Examination in June 1948 revealed a $\frac{3}{4}$ inch increase in length of the right lower extremity. X-ray films made in June 1948 of both legs in anteroposterior position reveal no defect in the bone but an increase in size of the bone both longitudinally and transversely. Note the greater distance of the transverse line of arrested growth from the epiphyseal plate on the right side compared with the left (Fig. 132 *right*).

SLIPPED FEMORAL EPIPHYSIS

The orthopedic surgeon is often perplexed by the number of cases of slipped femoral epiphysis that go along undiagnosed and untreated until serious complications result. The following report is typical of many of the cases that we encounter.

J. T., a girl aged 11 and obese, was first seen in June 1947 at which time the history obtained revealed that complaint of pain in right groin and knee had

been present for eighteen months and within the past four months she had great difficulty in walking. Her condition had been diagnosed as inguinal hernia, rheumatism of the knee and even psychoneurosis.

An examination revealed this child walking with a protective hopping gait bearing only slight weight on the toes of the right foot for balance. There was a
nt. There

133, left).

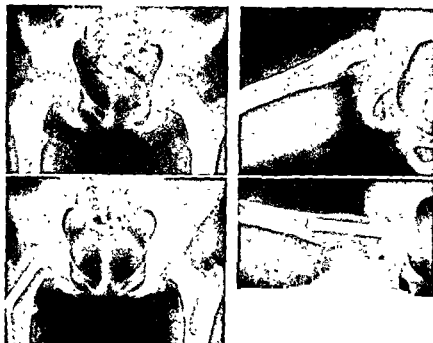


Fig. 133 (Patient J. T.)—Upper, Slipped femoral epiphysis right hip in a girl of 11. Lower, One year postoperative.

Through a Smith-Petersen incision the hip joint was approached by separation between the planes of the rectus femoris and tensor fasciae femoris muscles, and a cuneiform osteotomy was performed at the proximal end of the neck of the femur. The capital epiphysis was *freshened* with a curette, the dislocation reduced and a Smith-Petersen nail inserted to maintain the position.

Postoperative care consisted of skin traction for three weeks. Then the patient was allowed to be ambulatory with crutches but no weight bearing on the right side for a period of ten weeks. From this period on she was allowed to bear weight with crutches for four weeks at which time she was given a cane which she used about ten days.

Most recent examination revealed normal abduction, adduction, internal and external rotation and flexion is limited only 15 degrees. Her gait is normal.

X-ray film showed replacement of the epiphysis fixed with a Smith-Petersen nail. The head of the femur is viable (Fig. 133, right).

LEGG-PERTHES DISEASE

F. S., a boy aged 6 years, was first seen in August 1942 at which time his mother stated he has been walking with a limp on the right side.

Examination revealed limitation of motion in all directions at the right hip joint due to involuntary muscle spasm. There was only a slight amount of atrophy of the right thigh.

X-ray films revealed typical finding of Legg-Perthes disease with the aseptic necrosis and flattening of the capital epiphysis with a broadening of the femoral neck (Fig 134, *left*).



Fig. 134 (Patient F. S.) —*Left*, Legg-Perthes disease of right hip in a boy aged 6. *Right*, Six years later. Satisfactory result obtained with full weight bearing allowed during this time.

The mother was told to restrict the patient's activities as long as he had pain—that he should be put to bed when the pain became severe. However, this child insisted upon carrying out his usual routine as going to school and playing with the "kids" after school. At no time was he in bed for the disability nor did he wear a brace or cast.

When the boy was examined June 21, 1948 his gait was normal. Motion at the right hip joint was limited in motion only 15 degrees in internal rotation. Motion in all other planes was normal.

X-ray films made on March 15, 1948 revealed a complete regeneration of the head of the right femur although it is larger than the left (Fig. 134, *right*).

PRONATED FEET

We cannot go into a full discussion on this subject but I have never become too much concerned with children's feet as long as the calf was of sufficient length and the tread of the shoe revealed more wear on the outer half of the heel and sole.

If the foot is flexible and asymptomatic but wear occurs mostly on the inner half of the heel and sole, a rigid shank shoe with an elevation on the inner borders usually suffices.

From my observation steel plates or felt pads inserted into shoes have had little influence on correction of pronated feet in children. Among

other objections is that a shoe larger than is required for good fitting is necessary to accommodate these devices.

Exercises to invert the foot and flex the forefoot have not been successful in correction of pronated feet because in order to develop muscles to accomplish a satisfactory result many hours of the day must be devoted to this form of treatment. I have never met a child who would spend



Fig 135 (Patient J. D).—*Upper*, Weight-bearing film of foot in a girl aged 9
Lower, Weight-bearing film four months following scaphoid-cuneiform arthrodesis

most of his play time exercising his feet and I can't blame him much for his attitude.

Sight must not be lost that with every step a child makes he is exercising his feet and if he has the proper foot gear I do not think that there is much to worry about.

However, if a child has painful pronated feet in which all causes

of pain other than the pronation are excluded an operative procedure is definitely indicated to alleviate the disability.

J. D., aged 9, was admitted to the hospital in November 1935 with the history that she could walk only a few blocks when her feet became so painful she was forced to sit down.

There was no evidence of disease generally or locally to account for the complaint of painful feet. The calf groups were of sufficient length. The feet pronated markedly on weight bearing (Fig. 135, upper).

A scaphoid-cuneiform arthrodesis was performed on November 5, 1935 following which casts were applied with the feet held in position of cavus and varus. The casts were removed after eight weeks.



Fig. 136 (Patient E. H.).—A, rudimentary left limb with coxa vara due to incomplete development of femoral neck. B, Correction of coxa vara by subtrochanteric osteotomy.

X-ray films made with the patient on her feet four months after operation revealed an excellent restoration of the normal longitudinal and transverse arches (Fig. 135, lower).

AMPUTATION OF THE LEG

Children adapt themselves very quickly and very well to prosthesis and long before reaching adult life they are most proficient in handling themselves. However, recommendation of amputation for congenital defects in children often is met by objections from the parents or the child. It is here the inestimable value of the medical social service worker becomes a prominent factor in cooperating with the orthopedic surgeon in helping the patient and the parents through emotional and social problems which arise prior to and following the amputation.

Amputations may be performed as soon as the child can balance himself in the upright position but it is advisable to wait until training has



Fig 137 (Patient E. H.) —*Upper*, Following knee fusion and amputation of foot *Lower*, Self-retaining traction applied to stump immediately following amputation

been accomplished to avoid soiling of the prosthesis. However, conditions are not always optimum for early amputation. Amputations are not infrequently indicated in anomalous lower extremities as is demonstrated in the following case.

E. H., was first seen at the age of 2 years with incomplete ossification of the neck of the femur and coxa vara, rudimentary left femur, tibia and foot with an absence of the fibula (Fig. 136, A).

Before amputation could be considered further ossification of the femoral neck was necessary so that the coxa vara could be corrected. Also, because of the short femur and tibia further growth was also necessary before a fusion at the knee could be performed to provide a stump that would be adequate to receive the prosthesis. The coxa vara was corrected by osteotomy at the age of 7 (Fig. 136, B). The fusion of the knee was performed at the age of 11, followed in seven weeks by amputation at the lowermost portion of the tibia (Fig. 137, *upper*). Self-retaining traction was applied immediately following the amputation.

X-ray film and photograph made three years later shows the relative length of the stump (Fig. 137, *lower*).

Fitted with a suction socket limb this boy gets around exceptionally well.

FRACTURES

In our teaching we should emphasize that all fractures in children should be treated by the closed method with occasional exceptions. We are now experiencing a wave of open reductions in fractures of long bones in adults, and questioning the advisability of such treatment as a more or less routine measure is not for discussion here but unfortunately there are many who apply this method of treatment to children.

The growth factor plus Wolff's law do much to correct some severe malunions in children. Everyone treating fractures of children should by all means read the publications on this subject by Blount.

Fracture of Femur:

T. P., male, aged 10, sustained a simple fracture of the middle third of the left femur in May 1945. He was taken to a hospital where an open reduction was performed and the fragments fastened with a steel plate and screws. He developed an infection and drained pus until the plate was removed in February of 1946.

This child was admitted to the Children's Memorial Hospital in June of 1946 at which time the wound was healed but he had a marked outbowing and posterior angulation deformities. There was a broken drill point imbedded in the bone (Fig. 138 *upper*).

Operation was performed in which the drill point was removed and an osteotomy performed to correct the deformity (Fig. 138, *lower*).

It can be said that fractures of the femur in children should never require any operative interference for reduction. Adequate traction should be applied and as long as alignment is satisfactory in both antero-posterior and lateral planes an excellent result can be expected. If as much as 1 inch overriding occurs, overgrowth of the femur will, as a result of stimulation due to increased vascularity, compensate for the shortening. Fractures of the femur which are reduced with end-to-end apposition often result in an overgrowth of the extremity. I might say that maximum reduction must be obtained with the first week as calcium salts are laid down very early (Fig. 139, *upper*).

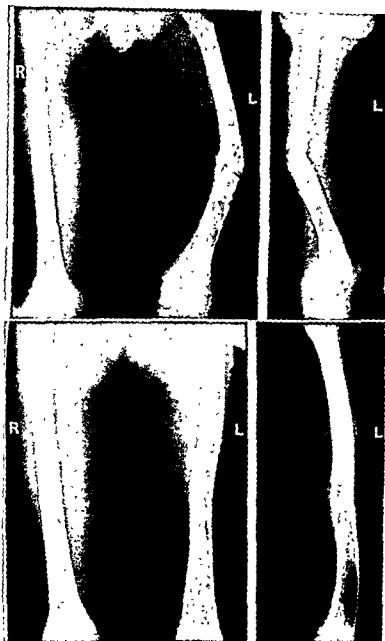


Fig. 138 (Patient T. P.) —*Upper*, Deformity of femur following open reduction and later removal of plate in a boy aged 10. Note broken drill point in shaft of bone. *Lower*, Two years after removal of fragment of drill and correction of deformity by osteotomy.

The perfect result in a case of symmetrical fracture in a child with 1 inch overriding is demonstrated in the following case:

V. C., aged 7, was first seen on June 14, 1944, with fractures of both femurs in their middle thirds. Overhead traction with 8 pounds of skin traction was ap-

plied for a period of five weeks, at which time there was enough callus formation that he could be placed in a double spica cast.

The cast was removed six weeks after it was applied.

X-ray films made four years later showed the perfect alignment which can be expected on any case treated similarly (Fig. 139, *lower*).

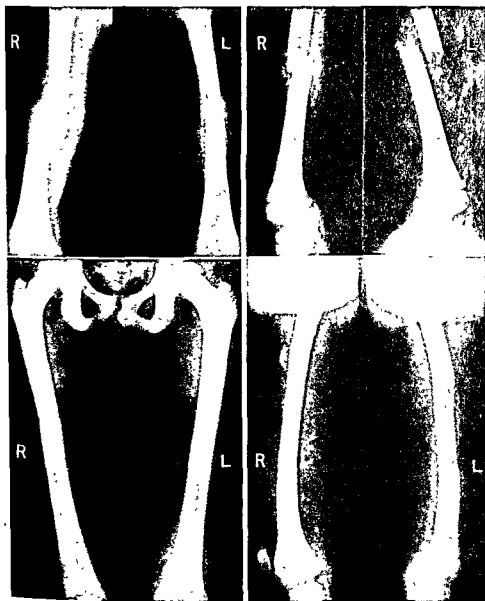


Fig. 139 (Patient V. C.).—*Upper*, Film shows overriding and early callus formation at the end of two weeks in a boy of 7. *Lower*, Anteroposterior and lateral views shows perfect anatomical restoration of both femurs.

Fracture of Radius and Ulna:

R. P., a boy aged 5 years, sustained fractures of the right radius and ulna in their middle thirds in June 1945. Fragments had been reduced, but not completely four weeks previously (Fig. 140, *upper*).

No treatment was prescribed at that time but two weeks later the cast was removed and the child allowed to use the arm.



Fig 138 (Patient T P) —*Upper*, Deformity of femur following open reduction and later removal of plate in a boy aged 10. Note broken drill point in shaft of bone. *Lower*, Two years after removal of fragment of drill and correction of deformity by osteotomy.

The perfect result in a case of symmetrical fracture in a child with 1 inch overriding is demonstrated in the following case:

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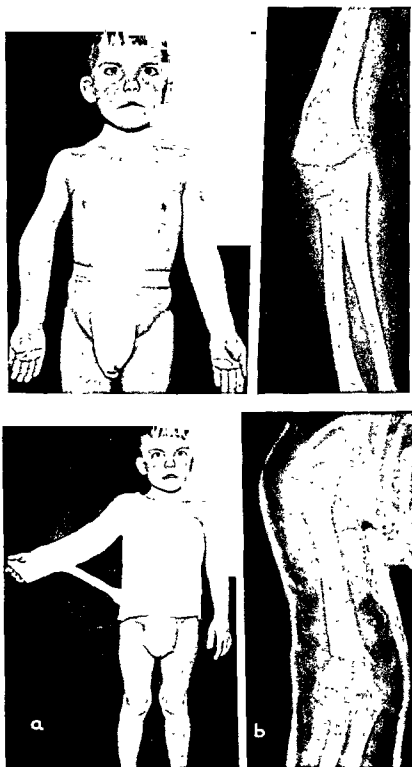


Fig 141 (Patient A D) —*Upper*, Cubitus valgus resulting from supracondylar fracture of the humerus in a boy of 4 years. *Lower*, Following osteotomy—spica cast applied (a) and x-ray film (b).

cuneiform osteotomy in the supracondylar region as is demonstrated in the following case:

A D, a boy aged 4, was seen . . .
supracondylar fracture c
sulted in a cubitus valgus

Through a lateral incision at the lower end of the right upper arm a wedge of bone made by two cuts in the humerus at right angles to its longitudinal axis, the base being $\frac{1}{2}$ inch long when the fragments were brought flush, the carrying angle was restored. A plaster spica cast was applied with the right forearm dressed in complete extension (Fig 141, lower).



Fig 142 (Patient A D) —Three years postoperative—photograph (a) and X-ray film (b)

The cast was removed after 5 -
turned

only
F
the lateral Spine.—Fracture . . .
is not a common fracture but whe
disability of the knee joint.

This is the case of J. B, a girl aged 7 who -
time a history was obtain-
taining an injury to left ki

... consisted of rest and hot

applications. No x-ray films were made. The child had limped ever since but in the last month she complained of pain in the left knee joint.

Examination revealed that motion of the leg at the knee joint was complete to flexion but extension was limited 15 degrees

X-ray films showed a triangular block of bone at the site of the tibial spine which was best visualized on the lateral view with the leg flexed at right angles.

Through a medial transverse infrapatellar incision, the knee joint was exposed and the factor causing the block shown in the x-ray film consisted of new bone formation at the site of the intercondylar eminence to which was attached the anterior cruciate ligament. The triangular piece of bone was resected with an osteotome. The anterior cruciate ligament was fixed to the site of the intercondylar eminence with a No. 0 chromic mattress suture by passing a bone-cutting needle through the raw bone surface. A long leg cast was applied which was removed at the end of four weeks.

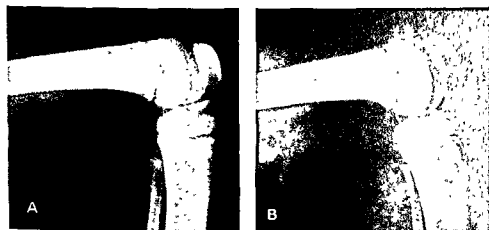


Fig. 143 —A, Fracture of tibial spine—film made six months after trauma to knee B, Film made three years after removal of displaced tibial spine.

Full range of motion at the knee joint returned with normal use three months postoperatively.

X-ray films made two and a half years later revealed a normal appearing knee joint (Fig. 143, A and B).

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SYMPOSIUM ON ABDOMINAL SURGERY

FOREWORD

This symposium on abdominal surgery is an attempt to put down the present state of our knowledge of some aspects of this vast field.

It is difficult to arrest the rapidly moving picture of surgical progress into such a still projection. The unfolding of the story during the past many laborious years is not portrayed and the directions into which the picture is moving can scarcely be indicated. Indeed, only fragments of one frame of the film can be presented.

It is obvious that the application of basic new concepts has accelerated the extension of surgery into broader fields; new antibacterial agents have changed the course and picture of surgical infections; and physiology and biochemistry are closer to clinical surgery. Herein are presented views on newer diagnostic measures, new technical procedures, applications of recent physiological and biochemical information, and the most up-to-date thought on the treatment of infections. Some principles recorded have been established on the basis of information hitherto unpublished.

Evidences of the dynamic state of our knowledge may be gathered from the fact that there is not complete agreement on all points amongst the contributors. This is healthy. Until sufficient knowledge is available to make all surgery unnecessary, complete agreement would be close to complacency.

Some of the contributions are re-statements of knowledge already gained and long used as part of a surgeon's equipment. This, too, is healthy. A survey of all accepted tradition in the light of each new step into the darkness is part of progress.

Grateful acknowledgement is extended to the contributors for their cooperation in creating this symposium.

JOHN H. MULHOLLAND, M.D.,
Consulting Editor

THE MANAGEMENT OF SMALL BOWEL OBSTRUCTION

W. ROSS McCARTY, M.D., F.A.C.S.*

INTESTINAL obstruction has always been a major problem on surgical services. Because of the frequency of abdominal wounds during the war and the large number of young men who have recovered from operation and injury, this condition may be seen more often in the future.

The approach to the problem should be physiological as well as surgical. Small bowel obstructions can be classified simply as external and internal. These two groups may be further subdivided into those in which the diagnosis has been established early and physiological changes are minimal, and those in which the diagnosis has been delayed and the distention and electrolyte imbalance are marked.

External obstructions are those in which the intra-abdominal contents, usually omentum and small intestine, protrude through congenital or acquired defects of the abdominal wall and become irreducible. Ventral, inguinal and femoral hernias compose most of this group, and as such are easily recognized not only by the physician but by the patient.

Internal obstructions, as the term implies, are those obstructions of small bowel occurring within the abdomen secondary to congenital malrotations, defects or bands; adhesions; internal hernias; volvuli; intrinsic lesions of the small intestine, such as benign tumors, neoplasms, gallstones, or other foreign bodies.

DIAGNOSIS

The early diagnosis of external incarcerated hernias can be made readily. In most instances there has been a hernia present for some time, and any change is appreciated by the patient and the physician. A reducible hernia in which obstruction occurs usually becomes irreducible, firm and painful; an irreducible hernia previously soft and asymptomatic may also become firm and painful. Accompanying these local findings there is an increase in the pulse rate, elevation of temperature, abdominal discomfort, anorexia and vomiting. These generalized signs and symptoms increase as the time element increases, until a full-blown picture of acute intestinal obstruction is present. Leukocytosis may be

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an indication of change in the bowel wall secondary to an embarrassed blood supply.

The early diagnosis of internal obstruction involving the small intestine is more difficult. The inception may occur as the classical picture: intermittent peristaltic pain increasing in frequency and severity, and associated with vomiting. Many of these patients have previously been subjected to abdominal surgery. These signs and symptoms together with a roentgenogram of the abdomen showing dilated loops of small intestine with or without fluid levels, make an early diagnosis comparatively simple.

The possibility of intestinal obstruction must be borne in mind in all cases of ill-defined abdominal pain, whether intermittent or constant, especially where previous abdominal surgery has been performed. Frequently, vague intermittent abdominal pain is disregarded by the patient and misinterpreted by the physician as being of little significance. The presence of bowel sounds or the history of bowel movements should never be taken as an indication that obstruction is not present. The importance of early symptoms may not be realized fully until distention, vomiting or even peritonitis develops. Here again early roentgenographic studies of the abdomen with the patient in prone, upright and lateral decubitus positions is of extreme importance. Dilated loops with fluid levels are diagnostic.

Severe abdominal pain and shock frequently accompany the onset of a sudden volvulus or internal herniation. Many of these patients are explored for an undiagnosed acute abdominal catastrophe and only at operation is the true cause ascertained. However, some patients following the onset of severe abdominal pain are comparatively free of symptoms and physical signs later when admitted to the hospital. If the patient is placed under surgical observation, and the cause of the abdominal pain was due to a volvulus or internal herniation, the true nature of the syndrome would not be appreciated until the abdominal pain had recurred or distention and vomiting appeared. A flat x-ray film of the abdomen of these patients taken soon after admission usually reveals a *hairpin or horseshoe type dilatation of a closed loop of* obstructed intestine. Check films will show this dilated loop to be consistently present but occasionally shifting to various parts of the abdominal cavity. These findings are indicative of a closed loop obstruction secondary to a volvulus or internal herniation (Fig. 144 and 145).

The diagnosis of late intestinal obstruction can be readily made. The clinical picture of marked distention, vomiting and dehydration is well known. The x-ray studies of the abdomen reveal the typical distended loops of small intestine with multiple fluid levels (Fig. 146).

Paralytic ileus secondary to surgical manipulation, or reflex, usually shows on x-ray a uniform distention of both small and large bowel.



Fig. 144



Fig. 145

Figs. 144 and 145.—Illustrating a closed loop obstruction due to volvulus. This gas-filled loop shifted about the abdominal cavity, but its general configuration remained the same. Similar closed loops due to internal hernia are more likely to remain in a fixed position.



Fig. 146.—Illustrating multiple fluid levels in distended loops of small bowel. This is a late state of the process. The patient was not seen until four days after the onset of intestinal obstruction.

EARLY INTESTINAL OBSTRUCTION

The management of early and late intestinal obstruction will be described separately.

There is general agreement that patients with early intestinal obstruction admitted to the hospital free of distention and in electrolyte balance should be operated upon immediately.

It seems logical that an indwelling intestinal tube should be passed on all patients, whether early or late. Many early cases with histories of recurrent attacks of intestinal obstruction have been relieved previously by intubation; patients presenting the possibilities of multiple adhesions, or those in whom there is partial obstruction aggravated by torsion or angulation may be completely relieved by means of the tube. Surgery can be avoided in many of these cases.

The frequently reported difficulty in passing the intestinal tube often arises from the relegation of this important task to an inexperienced or untrained individual. Most of the failures can be corrected by having trained personnel manage the initial and subsequent course of intubation.

It is not sufficient merely to pass the tube successfully and then expect the tube together with suction apparatus to overcome all obstructions by some magic formula. In properly managed cases distention and excessive intestinal contents of the small intestine proximal to the blockage will be relieved, and normal intestinal tone and peristalsis restored. The progress of the tube and relative position of the tip must be followed closely by repeated prone or upright x-ray studies taken every six to eight hours. In certain cases the tip will be observed to be approximately in the same position on succeeding x-ray plates with an increasing length of tube in the intestines. These findings represent the stoppage of the tube at the point of obstruction and with the feeding of the tube into the nostril of the patient an increasing length whips back and forth in the intestines (Figs 147 and 148). The term "whipping of the tube" has been coined for this condition. Failure to note this fact in the earlier studies of intestinal obstruction has resulted in unnecessary delay in surgical intervention.

This danger signal should not be overlooked. Confirmation of complete or almost complete block can be obtained by the introduction, without pressure, of a small amount of dilute solution of barium into the aspirating side of the intestinal tube. If a block is present the barium will be observed on the fluoroscopic screen to strike the impasse and flow upward along the tube (Fig. 149).

Lack of gaseous distention beyond this point is taken as an indication of a simple mechanical block. Fluoroscopic or x-ray evidence of a distended hairpin loop, or a distended long loop beyond the stoppage of



Fig. 147



Fig. 148

Figs. 147 and 148.—Illustrating "whipping of the tube." In Figure 147, the end of the tube has reached the site of obstruction. In Figure 148 the position of the end of the tube is unchanged but further tubing fed through the nose has coiled or "whipped" in the small intestine



Fig. 149.—Illustrating the localization of the obstructed site, in this case a large gallstone, by the instillation of thin barium mixture into the intestinal tube.

barium, is indicative of a closed loop type of obstruction. Armed with these facts the surgeon knows exactly what type and where the obstruction is located. In the first type the release of a simple mechanical block will usually relieve the obstruction and in the second type surgery is facilitated by the fact that the intestine above and below the obstructed loop is collapsed, and collapse of the obstructed loop can be readily managed at operation by the use of an aspirating syringe or suction catheter.

To repeat, early cases, in the absence of distention and electrolyte imbalance, are best operated upon soon. When patients are managed by the intubation method, supportive treatment must be adequately supervised.

LATE INTESTINAL OBSTRUCTION

When one is confronted with the problem of management of a patient in the late stages of obstruction, the philosophy of immediate surgical intervention does not apply. The mortality following immediate operation in this group is prohibitive, not because of the obstruction per se, but because of the superimposed derangement in fluid and electrolytes which at this point is the most lethal factor.

This deduction was the result of several observations:

1. The hopeless task of a surgeon trying to battle a mass of distended coils of small intestine in an attempt to relieve obstruction or close the abdomen.

2. The successful management by the intubation method of a large number of acute small bowel obstructions in soldiers with severe abdominal wounds where further surgery at the time would have resulted in increased mortality rate.

3. A ten year survey was made of the cases of intestinal obstruction admitted to the Third Surgical (New York University) Division of Bellevue Hospital, New York, between the years of 1935 and 1946. In this series of small bowel obstruction from all causes there were:

147 cases	54 deaths	mortality of 36.7 per cent
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A six year breakdown showed that from 1935 to 1940 there were:

65 cases	29 deaths	mortality of 44.6 per cent
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From 1941 to 1946 there were:

82 cases	25 deaths	mortality of 30.4 per cent
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Further analysis of those admitted seventy-two hours or more from onset of symptoms showed the following:

From 1935 to 1940 there were:

25 cases . 62 operated upon . 15 deaths . mortality 60 per cent

From 1940 to 1945 there were:

35 cases. 33 operated upon 18 deaths mortality 51.4 per cent

Therefore in this latter group there were:

60 cases. . 55 operations . . 33 deaths mortality 55 per cent

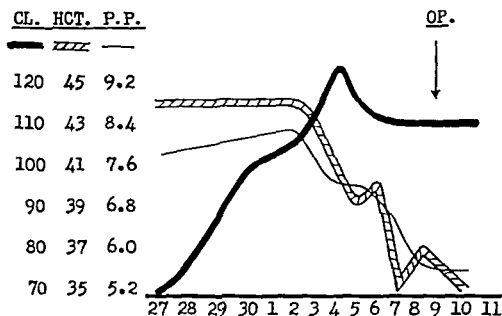


Fig. 150 —Graph illustrating relative values of blood chlorides, hematocrit and plasma proteins when first seen and on subsequent days of preparation for operation

These observations and study caused a change in the policy of handling cases seen late in the course of intestinal obstruction on the Third Surgical (New York University) Division, Bellevue Hospital.

Since 1946 an organized system was instituted to insure when possible that all patients with late intestinal obstruction be relieved of distention, and that fluid and electrolytes be brought into balance prior to operation.

A mimeographed copy of detailed instructions in the management of such cases was issued to each member of the resident staff.

From 1946 to 1947 there have been seventeen cases of late small bowel obstruction coming to surgical care seventy-two hours or more after onset. In this series there were thirteen operations with four operative deaths. There was also one nonoperative death in a patient admitted in extremis.

The relief of distention and the adequate correction of fluid and electrolyte balance required a prolonged preoperative period in most of these cases.

Herewith is an abstract of the history of one of the fatal cases:

An 85 year old woman was admitted with signs and symptoms of acute intestinal obstruction preceded by right upper quadrant pain. X-rays revealed gallstones lying within the abdominal cavity which on subsequent examinations were shown to be within the intestinal tract. The management was complicated by irrationality, incontinence, and the fact that the Miller-Abbott tube was removed by the patient on three different occasions in the early stages of treatment. Finally the patient was decompressed, electrolyte balance was attained and the site of obstruction was localized (Fig 150).

At operation, the stone was located easily and removed by a simple longitudinal incision in the terminal ileum. The proximal intestine was only slightly edematous showing that decompression had been adequate. There was no evidence of embarrassed blood supply. The patient was out of bed on the second postoperative day. Signs of cerebral vascular accident developed and death occurred four days postoperatively. This death was due to complications of the obstruction, the operation, and the patient's general condition. The obstruction itself was relieved.

SUMMARY

The number of cases of late (seventy-two hours or more) small bowel obstruction treated in this manner are too few to compare with the larger series in which operative procedures were performed before the distention was relieved or fluid and electrolyte imbalance corrected. But it would appear even in this small series of seventeen cases that careful preoperative preparation has lowered the mortality rate in this distressing condition.

1. The classification of external and internal obstruction of small intestine has been outlined.

2. The management of early and late cases of intestinal obstruction has been reviewed.

3. The importance of x-ray observation of the progress of the tube and localization of the obstructive site has been emphasized.

4. Attention has been drawn to the early diagnosis of acute volvulus and internal herniation.

5. A statistical study of the cases of small bowel obstruction admitted to the Third Surgical (New York University) Division, Bellevue Hospital, with the mortality rate is analyzed.

6. The advisability of early operation in acute intestinal obstruction when the patient is free of distention and in electrolyte balance is affirmed.

7. The high mortality rate in patients admitted seventy-two hours or more after the onset of obstructed symptoms is noted.

8. The importance of restoration of electrolyte balance and relief from distention prior to surgical interference in late cases of intestinal obstruction is discussed.

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THE MANAGEMENT OF MASSIVE HEMORRHAGE FROM THE GASTROINTESTINAL TRACT NOT DUE TO PEPTIC ULCER

J. WILLIAM HINTON, M.D., F.A.C.S.* AND DONALD A. DAVIS, M.D.†

ACCORDING to statistics compiled in different parts of the country, the incidence of massive gastrointestinal bleeding not due to gastric, duodenal, or gastrojejunal ulcer is between 25 and 45 per cent of all cases of massive hemorrhage from the gastrointestinal tract. The largest series reported is that of Allen,¹ who found that in a total of 2031 cases, 38 per cent were of this type.

Considerable confusion exists even among surgeons as to what constitutes massive gastrointestinal hemorrhage, and between internists and surgeons there is even greater difference of opinion. In this presentation, we are referring to patients who present the characteristic signs of shock: a blood pressure under 100, rapid pulse, perspiration, a blood count of two and one-half million or under, and with a hemoglobin of 50 per cent or under.

In patients over 45 years of age, *esophageal varices* constitute the most common cause of massive hemorrhage not due to ulcer. In making this diagnosis, the history is by far the most important factor, particularly if the patient has been an alcohol addict. The physical examination will frequently reveal an enlargement of the liver. An esophagoscopy following restoration of the patient's blood volume by repeated transfusions will confirm this diagnosis.

If the esophagoscopy reveals a definite point of bleeding, the use of oxyeel will produce gratifying results in some cases. As an elective procedure, Phemister² has resected the lower end of the esophagus containing varicosities by a transthoracic approach. In the majority of cases of this type the patient will respond to conservative management, and by correct dietary habits and discontinuance of alcohol in excessive amounts, a recurrence of a massive hemorrhage may be prevented for a period of years.

The following case illustrates the diagnostic difficulty in this type of massive hemorrhage.

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A man, 59 years of age, was admitted to New York Post-Graduate Hospital on May 16, 1945 with a history of hematemesis and melena for five days, accompanied by severe abdominal pain. In January 1945 gastrointestinal x-rays had revealed a duodenal ulcer. At that time the patient was having severe epigastric pain and hematemesis. For the past four months he had been following an ulcer regimen.

On admission the red blood cell count was 2,000,000 and the hemoglobin 24 per cent. Although a transfusion was started shortly after admission, the patient died six hours after admission. Autopsy revealed cirrhosis of the liver with esophageal varices and hemorrhage into the gastrointestinal tract without any evidence of a duodenal ulcer.

Peptic ulcers of the lower end of the esophagus are not generally appreciated as a cause of massive hemorrhage. We recently had a case in which a peptic ulcer produced a severe massive hemorrhage which was controlled by conservative measures. In 4000 consecutive esophagoscopies, Chevalier Jackson³ found peptic ulcers in eighty-eight cases, sixty-seven of which were considered healed and twenty-one active. In the active group the incidence of hemorrhage may be as high as 25 per cent.

Surgery is seldom necessary as an emergency procedure in the case of massive hemorrhage from an esophageal ulcer, but an esophageal ulcer may run the same course as a duodenal ulcer, resulting in complete stenosis at the cardiac orifice and necessitating an elective operation.

The following case illustrates the difficulty in determining the exact cause of the massive hemorrhage.

A patient, 52 years of age, was admitted to Bellevue Hospital July 9, 1946, with a history of pain in the right upper quadrant, vomiting coffee-ground material and tarry stools over a period of two weeks. At the time of admission, the blood pressure was 90/50, red cell count 2,300,000, and hemoglobin 5.5 gm. The patient continued to have coffee-ground vomitus for several days after admission. With multiple transfusions, a Sippy regimen and antacids, the bleeding ceased after one week. One month after admission, a gastrointestinal series revealed a periesophageal hernia, ulcer in the distal portion of the esophagus, and an ulcer in the first portion of the duodenum. It was believed that the bleeding was probably coming from the esophageal lesion or the periesophageal hernia. A transthoracic incision was made with removal of the eighth rib, and an ulcer was found in the lower inch of the esophagus which the operating surgeon perforated in mobilizing. The terminal esophagus was resected by esophagogastrostomy and an accompanying bilateral vagectomy. The patient expired on the seventh postoperative day. At autopsy there was no evidence of duodenal ulcer and it was found that death was due to mediastinitis.

We have had one case in which the stenosis at the cardiac orifice was complete, necessitating a gastrostomy. Since no improvement was

noted after a five month period, a transthoracic resection of the terminal esophagus with an esophagostomy was performed, and the patient was restored to normal. The permanent gastrostomy closed within two weeks time and after a follow-up of five years, the patient is perfectly well.

Hiatus hernia is rarely thought of as a cause of massive hemorrhage, but in the past three years, we have had occasion to operate upon five patients in whom massive hemorrhage was attributed to a definite hiatus hernia with erosion of the gastric mucosa or to a superficial gastric ulcer.

This condition may be overlooked unless the possibility of a hiatus hernia is borne in mind and a gastrointestinal study confirms or excludes this condition. In our group of cases, a transthoracic repair of the hernia was done with an accompanying transthoracic vagotomy.

Carcinoma of the stomach frequently causes massive gastrointestinal hemorrhage. In the past four years there have been four fatalities due to massive hemorrhage from a gastric carcinoma, as proved by autopsy. If a gastric ulcer located on the lesser curvature can erode through and produce a massive hemorrhage, it is reasonable to believe that a carcinoma situated on the lesser curvature could do likewise. If the hemorrhage is uncontrollable, a subtotal resection should be performed immediately. If the hemorrhage can be controlled by conservative measures, an elective operation can be done as soon as the patient's general condition warrants.

The following case illustrates the difficulty in diagnosing an early case of carcinoma of the stomach.

A man, 50 years of age, was admitted to New York Post-Graduate Hospital on January 20, 1940, suffering from hypertension. This condition was known to have existed for ten years. On admission the blood pressure was 200/130 and the patient had been having epistaxis for ten hours. After three days he was discharged from the hospital. He was readmitted on March 10, 1945, with a history of shortness of breath and weakness of two weeks' duration. Only a few weeks before admission he was complaining of anorexia. At 5:00 A.M. on the day following admission the patient was markedly dyspneic, the blood pressure was not obtainable and the heart rate was 122. He was conscious and complained of no pain, but presented the typical picture of shock. He became apprehensive and restless and died a half-hour later in spite of sedation. Autopsy revealed carcinoma of the stomach with hemorrhage into the gastrointestinal tract from the ulcerating carcinoma and secondary carcinoma of the lymph nodes, in addition to generalized arteriosclerosis and enlargement of the heart.

Other tumors of the stomach causing hemorrhage, which we have encountered in the past five years, are leiomyoma, leiomyosarcoma, and polyps. Usually the diagnosis of these lesions is not confirmed until

operation, but the x-ray findings suggest that the lesion is in all probability not a true carcinoma, but one of the rarer forms of tumors, and these tumors vary from really benign lesions to those of varying grades of malignancy.

Prolapse of the gastric mucosa through the pyloric sphincter is another source of massive hemorrhage, owing to erosion of the mucosa which is caused partly by interference with the blood supply. This diagnosis is usually made by gastrointestinal study, and the patient should be treated surgically as soon as his condition permits.

Gastritis may be so severe as to cause massive hemorrhages and this fact should be kept constantly in mind when all other diagnoses have been excluded. Hemorrhage from this type of gastritis may be so severe as to actually result in a fatality, and we have had one case which was proved by autopsy. The diagnosis can be confirmed by gastroscopy. These patients have a high free hydrochloric acid, it may be 60 to 75 units on a fasting stomach.

Carcinoma of the duodenum is not a common lesion, but it constitutes 50 per cent of all the malignant tumors of the entire small intestine. If the carcinoma is in the second or third portion of the duodenum, where they are usually located, it may erode into the pancreas, resulting in severe massive hemorrhage. At least four such cases have been encountered. If the carcinoma is in the third portion of the duodenum or around the ampulla of Vater the diagnosis may be difficult. If the gastrointestinal x-ray series does not establish the diagnosis, a study of the cell washings of the stomach may be the determining factor, and this should always be done in suspected cases of carcinoma of the duodenum.

Carcinoma of the jejunum and ileum is much less frequent than carcinoma of the duodenum. Of five patients with carcinoma of the jejunum who came to operation, one had massive bleeding associated with the lesion.

Meckel's diverticulum is not an uncommon site of unexplained gastrointestinal hemorrhage. There is usually gastric mucosa in the diverticulum and it will erode and ulcerate and produce massive hemorrhage. A small intestinal x-ray series will usually suggest the diagnosis.

Diverticulosis of the small intestine is rather uncommon; we have not encountered any hemorrhages associated with this condition.

In most lesions of the small intestine, the diagnosis may be facilitated by passing a Miller-Abbott tube into the upper jejunum and outlining the small intestine with thin barium as the tube descends along its course.

Carcinoma of the large intestine rarely produces severe massive hemorrhage. Chronic bleeding, of course, does occur, but in this presentation we are not concerned with that condition.

Diverticulitis of the large intestine is not an infrequent cause of massive gastrointestinal bleeding. In the past five years we have encountered six cases of massive hemorrhage directly attributed to diverticulitis of the sigmoid. As a rule, the diagnosis is easily made by a barium enema, and in all instances the hemorrhage has been controlled by dietary management and supportive transfusions.

Regional ileitis and ulcerative colitis cause massive gastrointestinal hemorrhage, but in these two conditions, the diagnosis is usually suggested by the fact that the patient is suffering from a chronic debilitating disease, and the diagnosis is confirmed by a gastrointestinal x-ray examination or a barium enema.

COMMENT

When a massive gastrointestinal hemorrhage is encountered, it can be fairly accurately stated that there is a 60 per cent chance that it is due to a peptic ulcer, and a 40 per cent chance that it is due to one of the lesions discussed in this presentation. In most cases of massive hemorrhage not due to an ulcer, the patient can be restored to normal by conservative treatment, provided adequate blood is given to compensate for the lowered blood volume.

For some of the lesions enumerated here, surgery may be advisable as an elective procedure to prevent the recurrence of the massive hemorrhage.

Blood dyscrasias have been intentionally omitted from this discussion since it is our intention to confine our remarks to lesions involving the gastrointestinal tract per se.

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OPERATIVE TREATMENT OF CARCINOMA OF THE DISTAL COLON AND RECTUM

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IN the past ten years the surgical literature dealing with colonic neoplasms has shown a consistent striving for greater individualization in this group of cases. Previously the combined abdominoperineal resection for carcinoma of the rectum, rectosigmoid and, in some instances, sigmoid, was the accepted routine procedure. There had been scattered voices speaking for procedures which would eliminate the need for colostomy, among them Babcock¹ and later Bacon.² The Miles' abdominoperineal resection had so much to recommend it that surgeons were loath to seek newer methods. It is a well-thought-out procedure, it permits a wide resection of the malignancy; and is attended by a relatively low morbidity, a low mortality and a satisfactory five year survival group. Thinking only of saving life, the surgeon felt that there was no justification for developing any other procedure. The few voices that were raised in opposition had only one thought in mind, making the life that had been saved a more livable one. Their proposals eliminated the need for a permanent colostomy.

With the changing attitude towards primary resection and anastomosis in the proximal colon as against the older Mikulicz and more recent obstructive resections, it is not unexpected that a similar reaction would appear in relation to tumors of the rectum and rectosigmoid.

Firor³ was one of the first to show that with proper preparation, primary resection and anastomosis in the large colon can be performed safely without proximal colostomy. Wangenstein,^{4, 5} acting on this suggestion, applied the same principles to surgery of rectal and sigmoidal tumors.

Anterior resection and anastomosis can be done in areas low in the rectum, provided that the patient is not too obese and the tumor is not too widely spread. The fact that it is a technically feasible operation is not enough to justify its use. The procedure can be done in many cases where it should not be done for other reasons. Included in this series of anterior resection and primary anastomosis for carcinoma of the rec-

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tum and rectosigmoid, are only those cases in which it became necessary to free the rectum from the hollow of the sacrum in order to achieve the anastomosis. In some instances this was all the mobilization necessary. In other instances the rectum had to be freed from the anterior structures as well.

In performing this operation the proximal resection is as wide as in abdominoperineal resection. The superior hemorrhoidal artery is ligated at the same point and the proximal sigmoid or even descending colon can be mobilized to be brought into the hollow of the sacrum for anastomosis without tension. The only diminution in the breadth of the resection lies in the segment distal to the tumor.

The area below the tumor, through which extension of malignancy may be expected, should determine the length of distal segment that one must resect. Generally, in colonic tumors elsewhere, 4 to 5 inches on each side of the lesion with a good segment of mesentery is considered ample resection. Is this true in the rectum? In other words, is there evidence that sectioning the gut 2, 3 or 4 inches below the lower edge of the tumor would give an adequate assurance against leaving tumor behind in the gut wall?

This discussion concerns an area of the large intestine from the anus to some 15 to 18 inches proximal to the anus. It is not felt that this area can be considered as a unit from a surgical point of view, separate thought and different surgical approaches should be applied to conjoint sites. A paper by Charles Mayo⁶ in 1943 had as its title "One-stage Combined Abdominoperineal Resection for Malignant Tumors of the Rectum, Rectosigmoid and Lower Sigmoid." This group of tumors, some within an inch of the anus and others as far as 10 to 12 inches from the anus, were treated in the same way, abdominoperineal resection with a permanent inguinal anus. Lahey⁷ in 1946 writes, "I can discuss the selection of one-stage abdominoperineal resection of the rectum together with the possible selection of an operative procedure for this lesion, which is concerned with preservation of the sphincter, either by implantation of the upper segment of the colon into the perineum or by pelvic anastomosis with preservation of the rectal stump, by saying we do not employ the latter operation (preservation of the sphincter)." As to the extent to which the abdominoperineal resection is stretched he states "When the lesion is in the lower loop of the sigmoid where an inadequate amount of bowel tube remains below for the application of the modified Mikulicz procedure, it is our opinion that in such cases the abdominosacral type of operation is to be preferred rather than any type of resection with pelvic anastomosis."

Aside from a growing disagreement about the use of the modified Mikulicz procedure in tumors anywhere in the large bowel, as against

primary resection and anastomosis, it seems difficult to be persuaded that just because there is lacking the necessary 3 to 4 inches of sigmoid for exteriorization on the skin surface, a patient should be condemned to a life with a colostomy. As will be shown below, there is no evidence that a tumor in the sigmoid spreads downward into the sacral hollow.

There are two thoughts that this paper seeks to emphasize. The first is that tumors of the sigmoid and rectosigmoid should not be lumped with tumors of the rectum and should be accorded special thought in surgical approach. The Miles' abdominoperineal resection should not be employed for tumors in this area without a definite reason. The second point deals with tumors of the rectum proper. In this group of lesions, we feel that there is ample evidence to warrant a division of the upper from the lower rectal lesions and abdominoperineal resection should not be performed out of habit, but because the location and the pathology warrant its use.

HISTORICAL REVIEW

A brief review of the procedures employed before Miles'⁸ introduction in 1908 of the abdominoperineal resection will furnish reasons for its immediate acceptance, its continued popularity, and its establishment as the standard procedure for tumors of the rectum. The contributions were concerned with hiding the artificial anus in the sacral area or attempting to maintain continuity by anastomosis, usually performed either through a sacral or abdominal approach or both. Kraske⁹ did a posterior resection with a sacral anus; Hochnegg¹⁰ pulled the proximal segment through a partially remaining external sphincter. Quenu¹¹ did an anal dissection within the anal sphincter, pulled the proximal segment through the incised sphincter and sutured it to the anal skin. Lockhart-Mummery¹² attached a rubber tube into the proximal segment, invaginated it into the distal segment and fixed it in place by several sutures.

The posterior resections were unsatisfactory because of the difficulty encountered in getting well above the tumor, the lack of knowledge concerning local and hepatic involvement and an uncontrollable sacral-anus. When an anastomosis was done through the posterior approach there were the same objections plus the added difficulty of performing the anastomosis without tension. This resulted in leakage, infection, strictures and fistulas. When successful, there was the advantage of a normal sphincter-controlled rectum.

Miles recognized the inadequacy of these procedures, and was strongly influenced by the pathological studies on lymphatic spread made by Poirier, Cunco and Delamere.¹³ Poirier and his co-workers presented evidence that lymphatic spread from carcinoma of the rectum was up-

ward, laterally and downwards, and Miles planned his procedure to eradicate all routes of spread. He shifted the emphasis from local inadequate surgery to life-saving surgery on the grounds that colostomy is the price a patient must pay if he wishes to continue to live. The criterion demanded by cancer surgery—wide resection of the growth and maximal removal of actual and potential lymphatic spread—is met.

Could a procedure be devised combining the advantages of Miles' procedure and yet eliminating the need for a permanent abdominal anus? A colostomy at worst is an ugly, unnatural, social menace, which may ruin a patient's zest for living and leave him with the thought that he has achieved, not a prolongation of life but a postponement of death. At best, a well controlled colostomy is compatible with near normal living, and patients become conditioned to their new status and carry on an acceptable existence. Despite such acceptance, however, any procedure by which normal continuity can be established with an equivalent operative risk and a comparable long range survival percentage, deserves a careful trial. A sometimes forgotten sequel of abdominoperineal resection is impotence, reported by Jones²⁵ as occurring in 95 per cent of patients.

In 1942 Firoz² published a series of cases of anterior resection and primary anastomosis without proximal colostomy for colonic tumors with preoperative preparation by adequate decompression, nutritional rehabilitation, blood replacement, intraluminal bowel sterilization and systemic antibiotic therapy. His results were sufficiently encouraging to warrant wider use of the procedure. Today there is a general tendency to replace the Mikulicz¹⁴ procedure by resection and primary anastomosis without proximal colostomy, and the discussion now deals less with justification of the procedure than with the details of the primary anastomosis, i.e., closed versus open. This tendency in other regions of the colon is mentioned because it furnished the impetus to apply the same principle to lower-lying lesions in the sigmoid and rectum. Such application presented two important problems. First, the danger of inadequate excision below the lesion to meet the principle of radical regional excision for malignancy, secondly, the technical difficulty of achieving a satisfactory anastomosis in the cramped quarters of the pelvis.

Miles was led to his decision by the pathological studies of Poirier and his associates. The logical approach to the problem was a reexamination of those pathological conclusions in the light of our present-day methods of careful pathological examination by gland-clearing method, introduced by Gilchrist.¹⁷ We now have reports from several sources—Coller, Kay and MacIntyre,¹⁸ Gabriel, Dukes and Bussey,¹⁶ Gilchrist and David,¹⁷ Grinnel,¹⁸ Glover and Waugh,¹⁹—all of whom agree generally that Poirier was right about upward spread, that lateral spread

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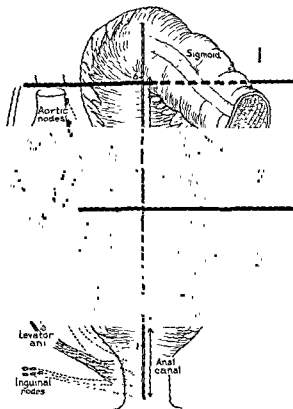
may and does occur along the levator ani fascia, but that downward spread, which is the crux of this problem, is of infrequent occurrence and of negligible importance, and then only when proximal spread has been massive. Glover and Waugh¹⁹ in 1946, on a study of 100 cases with already existing advanced proximal spread, concluded that 0.5 per cent may spread distally and that, if the rectum is sectioned a minimum of 2 cm. below the grossly palpable lower edge of the tumor, the danger of leaving tumor behind is negligible. Grinnel¹⁸ concludes: "Downward lymphatic spread is exceedingly rare in operative specimens and occurs only by retrograde flow when the high nodes are blocked. The rare occurrence of downward extension suggests that the operation of anterior abdominal resection with ligation of the superior hemorrhoidal vessels may have a wider field of usefulness for tumors near the rectosigmoid junction." Gilchrist and David (Surg., Gynec. & Obst., March, 1948) state "Retrograde metastases to nodes 1 to 5 cm. below the tumor occurred in 7 out of 153 tumors below the promontory of the sacrum (4.6 per cent)." They do not state whether these cases already had proximal lymphatic blockage. From these studies it would seem that the danger of downward spread, which drove Miles to an insistence on removal of the lower segment, is not as important a factor as believed.

Black and Waugh,²⁶ in reporting local spread in the wall of the colon in left-sided lesions, state "For resections of the left part of the colon for carcinoma only 2 cm. of normal bowel need be allowed above and below the lesion in order to remove the whole of the primary lesion."

The fixed rigidity denying all consideration for any procedure other than abdominoperineal resection in all segments of the rectum, seems unjustifiable. Gilchrist, in a study of local recurrences following abdominoperineal resections, points out that the rectum may be divided into two sections; the lower, completely extraperitoneal portion extending 3 to 4 inches above the anus, and the higher intraperitoneal portion. The latter segment is that portion which has peritoneum on its anterior surface, its posterior surface lying along the sacral hollow. In the extraperitoneal group the local recurrence rate was 23.2 per cent, in the intraperitoneal group, 3.6 per cent. The local recurrence rate in the latter group so closely approximates the rectosigmoidal and lower sigmoidal lesions that he groups them together in his statistical report. It is in this intraperitoneal group that anterior resection with primary anastomosis deserves consideration.

Those above this 4 inch line, shown in Figure 151, fall into the controversial group. The decision as to the procedure to be used, should depend upon the pathologic findings. Wangenstein states the case as follows: "It is to be admitted freely that this operation (anterior resection and primary anastomosis) cannot compete in all cases of rectal

cancer with the abdominoperineal operation. It is immediately apparent that its employment is contraindicated in juxtasphincteric malignancies on the score of inadequate removal of the local lesion, furthermore, in all lesions at the level of the levator muscles, the operation is contraindicated on the score that this procedure does not permit division of the levator muscles and adequate removal of the lateral lymphatic spread. Hence, in all large fixed ampullary lesions in which the tumor has



[Fig 151.—Area 1 Anterior resection and primary anastomosis Area 2: Anterior resection and primary anastomosis if lesion is not far advanced Area 3. Abdominoperineal resection.

extended beyond the confines of the fascia propria of the rectum and a real opportunity exists for lateral spread in the lymphatic zone, ampullary resection should not be undertaken. Apart from these considerations the operation of ampullary rectal resection would appear to deal as well with the problem of rectal cancer as does the abdominoperineal operation."

As for the tumors of the rectosigmoid and lower sigmoid, it would seem that some special reason should be present to justify abdominoperineal resection and permanent colostomy. Charles Mayo, quoted

above as of 1943 when he lumped rectum, rectosigmoid and lower sigmoid as one group to be treated by abdominoperineal resection, has this to say in 1948²² in a report of 200 cases of anterior resection and primary anastomosis for lesions situated 5 to 15 cm. above the anus, "If it is properly performed, and if adequate resection is possible, it is comparable in radicalness to the combined abdominoperineal resection."

How important, in terms of numbers of patients, is it to separate the lower sigmoid and rectosigmoid tumors from those of the rectum? Pemberton and Dixon²¹ give the following sites of occurrence in a series of 3542 cases:

	Cases	Per Cent
Cecum	211	6.0
Colon to sigmoid.	602	17.0
Sigmoid	480	13.0
Rectosigmoid	627	18.0
Rectum . . .	1,599	45.0
Anus	23	0.6
	<u>3,542</u>	

In such a group, half of the sigmoid tumors (the lower half), all the rectosigmoid and rectal tumors would be removed by the abdominoperineal resection with permanent colostomy, a total of 2466 cases. We feel that the sigmoid half and the rectosigmoid group can be expected to do as well by primary anastomosis, a total of 867 cases, or 35 per cent who could be spared permanent colostomy and be expected to show a five year salvage comparable to the abdominoperineal resection group. That figure omits completely any of the rectal tumors. Of these, a certain percentage would be high enough to permit anterior resection, probably 10 to 15 per cent according to the location of tumors listed by Bacon² in a collection of 1401 cases distributed as follows:

	Cases	Per Cent
Sigmoid.	315	22.5
Rectosigmoid .	231	16.5
Rectum—5th inch	148	10.6
4th inch	211	15.0
3rd inch	228	16.3
2nd inch	126	8.9
1st inch	74	5.3
Anal canal	68	4.9

Close to 50 per cent, then, of patients now being subjected to a life with permanent colostomy could continue with normal bowel continuity. This leaves the lower two-thirds of the rectum for abdominoperineal resection or such procedures as Bacon's "pull-through" procedure through an intact external sphincter from which he reports 60 per cent

continence and 40 per cent being uncertain enough to require the wearing of a pad.

SELECTION OF CASES FOR ANTERIOR RESECTION AND PRIMARY ANASTOMOSIS

On the Third New York University Surgical Division at Bellevue Hospital, *anterior resection and anastomosis* is being performed for lower sigmoidal and rectosigmoidal lesions, and those rectal lesions above 5 inches from the anus, unless local pathology, size of tumor, penetration of lesion, adjacent inflammatory or malignant attachment make the procedure not feasible. For those tumors lying 3 to 5 inches from the anus, *anterior resection* is done for early small lesions when 3 to 5 cm. below the lower edge of the tumor can be removed. Those within 3 inches of the anus are removed by abdominoperineal resection.

In the presence of incurable distant metastases to liver or periaortic nodes, an effort is made to do anterior resection and anastomosis in all rectal lesions regardless of location, since cure is no longer the problem. The situation seems to require a philosophic approach to the problem, rather than surgical judgment. We feel that these patients will live more comfortable lives for the short span they have left and should not be further punished by having to carry a colostomy for that period. If, because of local pathologic changes, anastomosis cannot be done, and the tumor is locally resectable, an abdominoperineal resection is performed to rid the patient of the bleeding, ulcerating, infected mass. The removal of the tumor makes the colostomy controllable, whereas in its presence it constitutes a source of irritability, inducing reflex peristalsis of the colon and repeated evacuation, which cannot be controlled by the usual methods of diet, irrigation or drugs.

We include in the group of anterior resections only those cases in which it is necessary to mobilize the rectum from the hollow of the sacrum in order to achieve the anastomosis. Any lesion in the sigmoid, which can be removed with a sufficiently wide distal margin without mobilizing the rectum from the sacrum, is included with the general colonic group of tumors for which resection and primary anastomosis exclusively have been done for the past five years. The Mikulicz or modified Mikulicz procedure is not employed, nor is the two-stage abdominoperineal resection described by Lahey. A patient who is admitted with obstruction which cannot be relieved by conservative methods is decompressed surgically by a loop colostomy of the proximal transverse colon (high in the right upper quadrant), followed in two weeks by definitive care of the local lesion and later closure of the colostomy.

ANALYSIS OF RESULTS

The statistical reports on anterior resection and primary anastomosis deal only with short time follow-ups, and with immediate postoperative morbidity and mortality. Mayo and Smith²² report 200 cases with nine deaths, three of these deaths occurring in patients with accompanying colostomies, and six in patients without accompanying colostomies. Four of the six deaths in the latter group were due to pulmonary embolism or were of cardiovascular origin. Waugh and Custer²³ report sixteen cases, only one of which was in the rectum, fourteen in the rectosigmoid and one in the lower sigmoid. There was one death from extensive bronchopneumonia and atelectasis on the fifth day. At necropsy the anastomosis in the rectosigmoid was found to be "in excellent condition." Wangenstein reports a series of thirty-five ampullary resections (excluding rectosigmoid) with two hospital deaths, one due to coronary thrombosis and the second due to pyelonephritis and oliguria, which he attributes to the injudicious administration of sulfathiazole, a mortality of 5.7 per cent. Dixon²⁴ reports 426 cases with twenty-five deaths, a mortality rate of 5.9 per cent. It is interesting that eighteen of these followed the first stage of the operation and seven followed closure of the proximal colonic stoma. The mortality from the closure of the colonic stoma should be weighed against the supposed hazards of resection without proximal colostomy. Of the 426 cases, 270 were done in recent years under present day preoperative and postoperative care, with a mortality of 2.6 per cent.

On the whole, the mortality rates are lower than most reports on abdominoperineal resection; the morbidity is less, most patients leaving the hospital within two to three weeks, with a healed wound, and having normal bowel movements.

Our series consists of forty cases, the location of the reaction ranging from 3 to 10 inches above the anus. Early in the series we performed this procedure for tumors situated lower than we would today. The lowest anastomosis could be felt 2 inches within the anus in a thin man who lived two years and died of an independent carcinoma of the lung. Autopsy showed no local recurrence in the pelvis or liver. We have had two deaths, one in an obese woman of 45 whose lesion was discovered during routine sigmoidoscopy 5 to 6 inches above the anus. At operation severe bleeding from a cluster of paraovarian varicosities was controlled with difficulty, and the patient's circulation failed on the table. Circulatory competence was restored by transfusion. She did poorly post-operatively, became markedly distended and died on the fifth day with consolidation of both lungs and probable peritonitis. The second death occurred in a woman of eighty with a perforating carcinoma of the

ampulla at the rectosigmoid and adherence to the left wall of the pelvis. It was considered inoperable, but in an effort to delineate its attachments, a friable portion of the tumor was torn. Because of the open rectum, it was decided to resect the mass. This was done incompletely because of adherence to the side wall, and an end-to-end sigmoidorectal anastomosis was performed. The patient did fairly well for the first four days. She had her first bowel movement on the fourth day. On the fifth day she developed tracheal edema with submucosal hemorrhagic exudate which was considered a late effect of intratracheal intubation. On the sixth postoperative day the edema completely occluded the trachea and before tracheotomy could be performed the patient died. At autopsy the peritoneum was clean, but there was a local abscess containing 10 to 15 cc. of pus about the anastomotic site. There was no leakage from the anastomosis.

Five of the forty patients had obvious liver metastases at the time of operation. Four of these patients lived four, six, six and eight months, having normal bowel movements. The fifth patient was operated on in December 1947, she had two nodules in the liver. She is alive and well with normal bowel movements at this time, ten months after operation.

Five patients required resection of other organs because of adherence, one a hysterectomy, another a hysterectomy and omentectomy (this was a leiomyosarcoma involving rectum and uterus, probably originating in the uterus but this could not be determined), one a resection of the left ovary, tube and adherent omentum, and one a resection of a segment of the dome of the bladder.

Two cases required previous decompressing colostomy for acute obstruction on admission. The remainder had no proximal colostomy done at operation. In one case this was an error. We feel that as a routine procedure, proximal colostomy is not necessary, but if there is any doubt about the viability of the gut edges or the adequacy of the suture line, a proximal colostomy should be done. Our view is that one must explain its need. The more carefully the patients are prepared, from the standpoint of tube decompression, the less need will there be for a proximal colostomy.

Among the complications there were three fistulas, one drained sacally and closed in thirty-four days; one drained abdominally and closed in twelve days; the third failed to heal and was found to be the seat of a recurrence at the site of anastomosis, obviously an inadequately resected lesion. A bladder injury was repaired, and drained for six days by urethral catheter with uneventful recovery.

Of two males 37 and 47 years old respectively, neither became impotent following surgery.

Three cases were poorly chosen, the lesions being too close to the anus. Today we would perform abdominoperineal resection for these.

None of the recovered patients have developed strictures at the site of anastomosis; they move their bowels normally without complaint.

PREOPERATIVE PREPARATION

In preparation for surgery two related but distinct problems must be solved. First, the establishment of a normal, or as near normal a patient as the disease permits. The preparation of a patient for major surgery today has become more or less a standardized matter. Hemoglobin levels should be within normal limits, bearing in mind the work of Lyons²⁷ on chronic shock; transfusions should not be measured in liters, but in terms of the patient's blood volume and hemoglobin content. Reproteinization can be achieved by a high protein diet, 125 gm. a day, with a sufficiently high carbohydrate diet to meet the caloric needs of the patient—a minimum of 3000 to 4000 calories. If added proteins are needed, commercial dried milk makes a palatable means of protein replacement. The various forms of amino acids are excellent but often so unpalatable as to diminish their usefulness. If Amigen is to be used, a simple way to prepare it is to mix 250 gm. of Amigen in 1000 to 1500 cc. of boiling water, add 500 gm. of dextramaltose (2000 calories). Stir, place in icebox and feed one-half to one glassful every three hours. If dried milk is to be used, 500 gm. of milk and 250 gm. of glucose or dextramaltose in 1000 to 1500 cc. can be administered in the same manner as Amigen.

Amigen contains 12 per cent nitrogen, dried milk contains about 5 per cent nitrogen; the body needs are 0.5 gm. of nitrogen per kilogram of body weight. Vitamins should be administered in larger than needed doses to err well on the overabundant side:

Vitamin C as ascorbic acid	500 mg a day
Vitamin B as thiamine hydrochloride	200 mg. a day
Niacin (nicotinic acid)	500 mg. a day
Vitamin K (in hypoprothrombinemia)	30 mg a day

The preparation of the bowel will depend upon the state in which the patient arrives at the hospital. If obstruction is acute, all efforts should be made to decompress the bowel by conservative medical means before resorting to surgical colostomy. The Levin tube and Miller-Abbott decompression from above, enemas from below, chemotherapy and antibiotics should be used with the hope that the obstruction is due to an inflammatory swelling (the more usual cause), rather than neoplasm itself. During this phase, parenteral rehydration and remineralization

and protein and blood replacement must be carried out since the oral route is barred. Decompression of the small bowel by the Miller-Abbott tube may lead one to error. Films of the abdomen will demonstrate the still distended large gut which calls for surgical decompression.

The decompression colostomy is done high in the right upper quadrant as a loop colostomy well away from the suprapubic incision to be used later. *If the colon is found hugely distended and thin-walled*, a needle puncture is made, the gas allowed to escape, and the loop brought out as a knuckle of gut over a glass rod. A cautery puncture can be made into the bowel within six hours, permitting gas to escape freely, and the gut is opened in twenty-four hours, the glass rod being left in situ to prevent recession of the bowel into the peritoneal cavity. When a proximal colostomy is done, two weeks is permitted to elapse for the gut to return to normal calibre and texture before the definitive procedure.

In the unobstructed lesions, preparation takes about a week. Sulfasuxidine, 12 gm. as the initial dose and 12 gm. in six divided doses each twenty-four hours thereafter, is administered for a week. If streptomycin is to be used for intraluminal sterilization, it should not be started until two or three days before the day of operation. Within forty-eight hours the bacterial count is at its lowest, it then rises each day. Whether sulfasuxidine or streptomycin is used, *near sterilization of the bowel* is accompanied by cessation of putrefaction and diminution in the production of vitamin K. Vitamin K should, therefore, be given in 10 to 20 mg. doses each day of drug administration gauged by prothrombin time determinations.

Cathartics are usually unnecessary, sulfasuxidine fluidifies the bowel contents sufficiently. For forty-eight hours preoperatively, the patient is on a fluid diet. If a primary anastomosis is contemplated a Miller-Abbott tube is passed thirty-six to forty-eight hours preoperatively. If abdominoperineal resection is planned, a Levin tube is inserted into the stomach the night before the operation. On the afternoon of the day before the operation, the patient is given a colonic irrigation, and every four hours thereafter a rectal tube is inserted and left in situ for ten to fifteen minutes to siphon off the excess fluid that may collect in the rectum. When the tumor is thought to be fixed in the pelvis, both ureters are catheterized the morning of the operation to make for easier identification in the pelvis. If the tumor is not fixed, a urethral catheter is fastened in the bladder the morning of the operation, and the bladder is emptied on insertion and later on the operating table.

The patient is seen by a member of the anesthesia department the night before the operation and the anesthesia problem evaluated. All patients are operated upon under inhalation anesthesia. We feel that

our postoperative morbidity with inhalation anesthesia in the hands of well trained anesthetists is minimal. Many clinics advocate spinal anesthesia and report excellent results with it. In outlying regions where excellent inhalation anesthesia is not available, spinal may carry a lower risk than inhalation poorly administered.

TECHNIC OF ANTERIOR RESECTION AND PRIMARY ANASTOMOSIS

The patient is placed in high Trendelenburg position; the shoulder braces should be rubber-padded, and placed over the acromion processes, not over the midclavicle. In the latter position in thin people, pressure on the brachial plexus may leave a disabling pressure neuritis. We have had two Klumpke's paralyses of the left arm, which had been held out on an arm board for intravenous infusion. As the surgeon working on the left side pushes the arm backwards against the fixed point of the shoulder brace, stretching of the lower cords of the brachial plexus occurs. This ulnar paresis is highly disabling and takes three to six weeks to clear. A leg vein should be used for infusion and if this is not available, the arm should be placed alongside the table with a curved band about it to protect the needle.

A left suprapubic, muscle-displacing incision is employed. In retracting the muscle laterally, the peritoneal fat should be carried with the muscle, for in it lies the deep epigastric artery which otherwise needs to be cut. The liver and periaortic nodes are explored, a self-retaining retractor inserted, and the pelvic area walled off from the upper abdomen. The local lesion is inspected and its location determined. The final decision as to abdominoperineal resection versus anterior resection need not be made at this time since the first steps are the same for both. The lateral and medial leaves of peritoneum are split down to the bladder in the male and the uterus in the female. The superior hemorrhoidal artery is identified, isolated, doubly clamped, cut and doubly ligated close to its origin. The left ureter is isolated and held by a loop of silk for later identification. The rectum is freed by blunt dissection from the hollow of the sacrum to the coccyx, the rectum is now straightened and is easily brought out of the pelvis. By this maneuver the cul de sac is made more shallow. The peritoneum across the bladder in the male or in the uterus in the female is cut, uniting the lateral and medial incisions of the pelvic peritoneum. A cuff of peritoneum is left on the rectum which is grasped by a series of clamps and while being held under tension, the cleavage plane between rectum and seminal vesicle in the male or uterus in the female is opened and the rectum freed to the prostate in the male, to the vagina in the female. The middle hemorrhoidal vessels are cut, then ligated, or if they can be previously identified, the vessels are clamped first and then cut and ligated.

The length of bowel below the lower margin of the tumor can now be definitely established. If there is 3 to 5 cm. and the tumor is free, the pelvis is carefully walled off from surrounding abdominal wall, and sectioned across at the selected level. The site of section of the proximal segment is now chosen and the bowel cut across, being sure that the proximal end will reach the distal end with no tension.

No clamps are used in this anastomosis. The lumen is swabbed out with moist gauze pledgets. If a two-layer anastomosis can be done, two layers are used. The first series of interrupted silk sutures is placed before tying any of them. As each suture is inserted a clamp is applied and as it is laid down it is covered by a piece of gauze so that each suture is separated from the next by a layer of gauze. This prevents snarling of the sutures. The two gut ends are then brought together and the sutures tied. A second layer of interrupted through-and-through sutures is now laid; each is no more than $\frac{1}{2}$ inch from its neighbor and these are tied snugly but not tightly. The admonition in tying is, "Caress it, don't kill it." The care with which these are inserted will often spell the difference between primary union of the anastomosis or breakdown with leakage. A cigarette drain from the hollow of the pelvis is brought out at the lower angle of the wound. The pelvic peritoneum is closed with interrupted silk and the abdomen closed in layers, using chromic continuous sutures to peritoneum, and interrupted silk sutures to fascia and skin. Blood transfusion is continued throughout the procedure and is regulated by the anesthetist as he follows the blood pressure of the patient, 500 to 1000 cc. may be used.

Complementary proximal colostomy is not used unless there is some doubt about the viability of the gut edges or uncertainty about the suture line, or edematous gut which had not been restored to normal character before operation. When required, a transverse colostomy is done and brought out through a stab wound in the right upper quadrant. Dixon's mortality figures show that seven of twenty-five post-operative deaths followed closure of the colostomy after the patient had recovered from the major surgical procedure. In our series of forty cases, no complementary colostomies were used.

POSTOPERATIVE CARE

Postoperatively, wound healing has been no problem; almost all heal by primary union. The first three or four days require parenteral fluid therapy. Fluids are allowed by mouth in forty-eight hours, the Levin tube being clamped off for an hour after each fluid intake. By the fourth day, a soft diet is permitted. The Levin tube or Miller-Abbott tube is removed by the fifth day; the diet is increased daily thereafter.

so that by the ninth or tenth day the patient is taking a liberal low residue diet.

The drain is removed on the fifth or sixth day. The first bowel movement occurs between the fourth and seventh days, and by the end of the second week, occurs daily. A rectal tube is inserted every four hours for ten minutes for the first forty-eight hours, to allow the escape of gas.

The patient is taken out of bed on the first postoperative day. Intraluminal chemotherapy postoperatively is not routinely employed; systemic penicillin is used postoperatively. Usually the patient is ready for discharge between the second and third week.

CONCLUSIONS

1. The lower sigmoid and rectosigmoid constitute an area of the colon which should be separated from the rectum proper, when dealing with carcinoma. Tumors in this area should be removed by resection and primary anastomosis. Thirty-five per cent of the tumors of the rectum, rectosigmoid and sigmoid occur in this area. This would eliminate colostomy for over one-third of the patients now being left with a permanent colostomy by the abdominoperineal resection. Difficulty in delineating exact boundaries of the rectosigmoid could be eliminated by including in it that portion of bowel completely covered by peritoneum.
2. Tumors of the rectum proper can be divided into four groups:
 - (a) Those situated 1 to 3 inches from the anus require abdominoperineal resection.
 - (b) Those tumors 3 to 5 inches from the rectum should have abdominoperineal resection if they are large, if the fascia propria of the rectum is involved, or if there is inflammatory or malignant attachment to adjacent pelvis. If the tumor is small, localized, does not penetrate through the serosa, and can be removed with 3 to 5 cm. of rectum below the edge of the tumor, it should be removed by anterior resection and primary anastomosis.
 - (c) Those tumors 5 inches and above the anus, if locally resectable, should have the preference of anterior resection and primary anastomosis, and only in cases of advanced pathology should an abdominoperineal resection be performed.
 - (d) In the presence of incurable metastases, resection and anastomosis is done whenever technically feasible.
3. The five year salvage percentage must await the passage of time to determine whether it will compare favorably with the abdominoperi-

neal resection. Dixon reports a 67.7 per cent five year survival rate in 272 patients.

With this division as outlined above, we feel that group I should offer just as good a prognosis without colostomy as by the abdominoperineal resection. If, to this group, are added those of the upper rectum and localized tumors in the middle rectum, over one-half of the patients previously accorded abdominoperineal resection can escape the need for an inguinal anus by utilizing the procedure of anterior resection and primary anastomosis.

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THE SURGICAL TREATMENT OF PANCREATITIS

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PANCREATITIS is a common disease, progressive in nature, varying in severity from mild edema to widespread necrosis, often associated with biliary tract disease and frequently unrecognized. Recurrent attacks may bring about complications which are considered as pathological entities but cannot be dissociated from the original physiological disturbance. The patient suffering from recurrent attacks of acute pancreatitis has been the unwitting victim of two popular misconceptions: that the diagnosis should be considered only when there is severe acute upper abdominal pain and profound shock; and that decompression of the biliary tract by cholecystostomy or choledochostomy is a beneficial procedure.

ETIOLOGY AND PATHOLOGY

It is our purpose to show that recurrent acute pancreatitis and its sequelae can be diagnosed and treated successfully by a definitive surgical procedure based on an understanding of the etiology and pathology. Herewith is an enumeration of salient observations made experimentally or clinically, contributing to this concept:

1. *A common passageway is present between the bile and pancreatic ducts.* In 1901, Opie¹ demonstrated that in individuals in whom the pancreatic duct empties into the ampulla of Vater above the papilla, obstruction of the papilla by a stone will allow bile to pass up the pancreatic duct and produce an acute inflammation. Archibald² showed that spasm of the sphincter of Oddi could produce sufficient obstruction to bring about the same result. Cholangiographic studies done by us³ in twenty-eight cases of recurrent pancreatitis demonstrated this common passageway in the majority. Reflux of pancreatic juice into the biliary tract, as evidence of a common passageway in cases of acute pancreatitis, was noted by Popper⁴ and in our studies.

2. *An emotional disturbance is the usual cause of dyskinesia of the sphincter of Oddi.* Aside from the very few cases in which obstruction of

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the papilla of Vater is due to an impacted stone, an aggravating condition in the emotional life of the patient was found to be the inciting cause of the attacks. Kymographic studies of the tonus of the sphincter of Oddi demonstrate how readily this muscle responds to emotional stimuli.⁶ Once an acute inflammatory attack has occurred, the sphincter of Oddi appears to become more sensitive, possibly due to inflammatory changes in that region, and the attacks recur with progressively shorter intervals until almost every meal brings on pain. The progressive nature of the disease is one of its most outstanding characteristics.

The emotional disturbances that affect the sphincter of Oddi may produce other effects on the gastrointestinal tract such as globus hystericus, cardiospasm, pylorospasm and spastic colitis. Dysuria and urinary frequency may also occur as a result of spasm of the bladder. Section of the sphincter will prevent biliary-pancreatic pain and acute pancreatitis, but an emotional crisis occurring in the future may cause any of the above disorders. These symptoms are often reflex in origin due to severe biliary-pancreatic pain and disappear after destruction of the sphincter of Oddi.

Other than emotional conditions which may produce reflex spasm of the sphincter of Oddi and result in pancreatitis are impacted gallstones, supraduodenal common duct stones, and duodenal diverticula arising close to the papilla.⁶

3 *The inflammation of the pancreas is initiated by the bile salts present in the bile.* In 1906, Flexner⁷ showed conclusively that the toxic factor in bile is the bile salts and that the degree of the inflammatory reaction is proportional to the concentration of the bile salts. This observation was confirmed by Archibald, Dragstedt⁸ and Ireneus⁹. Wangenstein¹⁰ showed that in cats in which bile was made to enter the pancreas, the incidence of pancreatitis was reduced by 50 per cent after cholecystectomy (i.e. the bile was low in bile salts due to the absence of the concentrating activity of the gallbladder).

4. *Alkalinization of the bile salt solution by pancreatic juice renders it toxic and thus it causes reactive edema and necrosis of the pancreas.* Flexner showed that buffered bile salt solution was less toxic than nonbuffered. The gallbladder is protected from concentrated bile salt solution by a mechanism which increases the acidity as the concentration increases.¹¹ Experimentally, a concentrated alkaline bile salt solution causes inflammation of the gallbladder.¹² Reflux of pancreatic juice into the gallbladder, making the bile alkaline, is a common cause of acute cholecystitis.^{13,14} However, the crucial experiment to establish unequivocally that alkalinization renders bile salts toxic to the pancreas has not yet been performed.

5. *Necrosis and hemorrhage, which sometimes follows the initial edema*

produced by the bile salts, is due to the action of trypsin which has been activated by dead cells and exudate. Purulent bile, even when the bile salt concentration is low, may be the cause of severe pancreatitis through trypsin activators such as streptokinase. Again, however, the crucial experiment to prove this concept that activated trypsin can digest tissues injured by edema has not been performed.

6. *Local effects produced by acute inflammation of the pancreas.* (a) *Biliary obstruction.* Acute swelling in the head of the pancreas may compress the common bile duct and produce temporary jaundice. Following many attacks with localized necrosis, the common bile duct may become narrowed, tortuous or even completely obstructed and distorted by the fibrosed head of the pancreas (Fig. 152).

(b) *Acute and chronic diabetes.* Swelling of the pancreas may interfere with the function of the islet cells and produce temporary diabetes associated with severe acidosis and glycosuria. Recurrent attacks may produce a chronic diabetes due to excessive destruction of the islet cells.¹⁵ This form of diabetes is especially sensitive to insulin since only small doses may produce hypoglycemia. Occasionally, the diabetes is masked due to the presence of a high renal threshold for sugar. The glucose tolerance test is a measure of the impairment of islet function due to gradual destruction of the pancreas.

(c) *Normal restitution.* In many patients even after numerous attacks of pancreatic edema without necrosis, the pancreas will be found normal when observed at operation. Biopsy specimens may show no changes.

(d) *Complete necrosis of the pancreas.* Occasionally an attack may produce generalized necrosis and hemorrhage followed in a short time by shock, collapse and death due to large losses of fluid into the peritoneal cavity.

(e) *Pancreatic cyst.* When an obstructed small duct empties into a necrotic area, a cyst which may grow to a very large size will form. Occasionally, such a cyst may become infected and abscessed.

(f) *Chronic pancreatitis.* Repeated attacks of pancreatitis with patchy necrosis may eventually convert the gland into a cirrhotic organ.¹⁶ This may result not only in diabetes due to destruction of islet cells but also to a deficiency in the formation of pancreatic juice. This reduction in external function of the pancreas can be measured by the secretin test. The spruelike syndrome of poor digestion, poor absorption of food and bulky fatty stool may result in loss in weight. Similarly, immediately following an acute attack, the production of pancreatic juice is markedly reduced for some days. As a result, diarrhea which may last from one to seven days frequently follows the onset of the attack.

(g) *Calcification of the pancreas.* Under certain conditions, calcium carbonate stones will form in the pancreatic ducts. These stones are

usually dendritic in shape since they form in the fine ducts and have extensions into smaller ducts which branch off at right angles to them. These stones obstruct the ducts behind them and lead to a compensatory hyperplasia in the unobstructed ducts.

(h) *Widespread inflammation of the upper part of the abdominal cavity followed by the formation of areas of calcification and fibrosis.* During a severe attack of pancreatitis, the voluminous exudate containing activated trypsin and other enzymes passes through the capsule of the pancreas, fills the lesser sac and pours out through the foramen of Winslow. This juice stimulates an inflammatory reaction around the gallbladder and over the dome of the liver which may pass down the right lumbar gutter and throughout the peritoneal cavity. The loss of fluids into the peritoneal cavity may be so great as to diminish blood volume and induce profound shock. Along with pericholecystitis the omentum, transverse colon, pylorus and duodenum may become adherent to the under surface of the liver. Areas of fat necrosis occur due to the action of lipase on free fat released by destroyed fat cells. The process may be localized to the right side and stimulate an attack of acute cholecystitis. Spread of this activated juice throughout the peritoneal cavity may cause paralytic ileus with x-ray evidence of distended small bowel loops and fluid levels.

During resolution, localized collections of fluid may accumulate below the diaphragm on both sides. This is especially prone to occur on the left side if the foramen of Winslow has been closed by previous attacks. The diffuse inflammation on the right side results in the formation of dense adhesions of the omentum and transverse colon to the gallbladder and porta hepatis. The duodenum may be deformed by these adhesions and during the period of chronic pain an x-ray diagnosis of duodenal ulcer is not unusual. The dome of the liver is not infrequently attached by dense adhesions to the diaphragm. The areas of fat necrosis may become calcified and these calcific nodules have been noted in the gastro-hepatic omentum, on the liver, and on the mesentery throughout the peritoneal cavity. These deposits have frequently been mistaken for evidence of healed tuberculous peritonitis.

(i) *Varicosity of the portal system.* We have noted in two cases tremendous enlargement of the veins overlying the gallbladder, common duct, pancreas and duodenum. These are apparently due to constriction or obliteration of the portal vein adjacent to the inflamed fibrosed pancreas. The presence of such varicosities make any extensive operation in this area extremely hazardous.

7. *General effects produced by acute inflammation of the pancreas.* (a) *Elevation of the serum amylase and serum lipase.* Loss of semipermeability of the fine pancreatic ducts due to the inflammation leads to the absorp-

tion of pancreatic enzymes into the blood stream through the lymphatics from the pancreas.¹⁷ This rise is especially prone to occur during acute edema of the pancreas. High serum amylase is diagnostic of acute pancreatitis and was applied as a practical test by Elman¹⁸ and later by Somogyi.¹⁹ It is now considered to be the most valuable test in the diagnosis of acute pancreatitis. If the edema is mild, there may be no rise in the serum amylase or it may be so transitory as not to be observed. If the destruction of the pancreas is extensive, there may be no rise in the serum amylase. In severe attacks, the elevation of serum amylase may persist for a week or longer; during the recovery phase, it may fall below normal values.^{20,21} In patients who have had many recurrent attacks, there may be no rise in the serum amylase even during a severe episode or it may be very low. We have had two cases in which the serum amylase was zero during an acute attack.

(b) *Elevation of trypsin in blood serum.* Although a rise in the serum trypsin has never been measured, there is evidence that widespread injury occurs due to an irritant (probably trypsin) circulating in the blood.^{22,23} Some of the observations are as follows: temporary hypertension; injury to the heart as evidenced by electrocardiographic changes²⁴; injury to the liver as noted experimentally by Archibald and Ireneus; injury to the kidneys as noted by transient and occasionally by permanent albuminuria; and subcutaneous hemorrhages.

8. *The pain in recurrent acute pancreatitis arises from two different causes—distention of the biliary pancreatic ducts, and inflammation of the pancreas and adjacent viscera.* Since spasm of the sphincter of Oddi is the basic factor in the production of pancreatitis, it follows that the biliary and pancreatic duct systems must be distended by the pressure necessary to overcome the abnormal resistance of the sphincter. This distention produces pain in the epigastrium with radiation to the back as well as to the right side (biliary) and the left side (pancreatic). When the sphincter is persistently spastic the pain may be either a constant ache or, if felt only after meals, it may last for one-half to four hours. That this type of pain is due to distention can be confirmed experimentally by sudden distention of the common duct through a T-tube or of the pancreatic duct through a fistula. Severe pain will invariably result. In each patient the individual preoperative pattern of pain is reproduced exactly, even if its location is bizarre (i.e., right lower quadrant, infra-umbilical, substernal, or radiation up the neck or down the arms). Radiation of pain beneath the left costal margin or to the back over the ninth or tenth ribs is evidence of pancreatic involvement. Confirmatory evidence that this type of pain is due to duct distention behind the spastic sphincter is the frequent occurrence after emotional disturbances, and occasionally relief by nitroglycerin.²⁵ The conclusive proof is the

fact that the pain disappears completely after destruction of the sphincter of Oddi.

Severe epigastric or back pain, squeezing, distending or burning in character, that occurs with active inflammation of the pancreas will last two to fourteen days if inadequately treated. Residual tenderness in the epigastrium and left upper quadrant is invariably present. If the inflammatory exudate spreads to the right upper quadrant, marked pain and tenderness of that point may be the predominating feature. After the exudate spreads throughout the peritoneal cavity, the whole abdomen may exhibit a peculiar type of superficial tenderness with generalized spasticity.

9. *The relation of alcohol to acute pancreatitis.* The high incidence of pancreatitis in chronic alcoholics has been noted. Whether or not alcohol has a specific action on the pancreas is not known. In our experience, pancreatitis occurs in an alcoholic on a spree who does not eat for several days and then has a meal containing fat. It can be easily visualized that when a gallbladder full of concentrated bile (due to starvation) suddenly empties into a pancreatic duct, a severe type of disease would ensue. This relationship of excessive alcoholic intake followed by a large, rich meal in the production of acute pancreatitis has also been noted by Paxton.²³ Whether the spasm of the sphincter, which is necessary for this event to occur, is due to direct irritation by alcohol or to the excessive gastric acidity produced by the alcohol is unknown. It must also be kept in mind that the alcoholic bout may be due to some unresolved emotional conflict which in itself may cause spasm of the sphincter.

DIAGNOSIS

The diagnosis of recurrent acute pancreatitis is based on: (1) the history and physical examination; (2) an elevated serum amylase during the height of the attack, (3) a secretin test showing diminished formation of pancreatic juice, (4) calcification of the pancreas in a patient with recurrent attacks of epigastric pain, the presence of a pancreatic cyst; a history of a previous operation at which pancreatitis was found.

Diagnosis during Acute Attack.—It is almost impossible to differentiate acute pancreatitis from perforating peptic ulcer, acute cholecystitis with or without perforation, acute intestinal obstruction, mesenteric thrombosis, or cardiac infarct, during the height of the attack. A high serum amylase is diagnostic and excludes the other conditions. A low serum amylase, however, does not always exclude pancreatitis, especially if performed two or three days after the onset. A careful history of past attacks and the results of x-rays, operations and the like may be of great help.

It is important to seek x-ray evidence of free air in the peritonea

cavity, since many of these patients have been treated for peptic ulcer because of the long history of recurrent attacks of pain after meals in association with some degree of duodenal deformity. In reviewing these x-ray findings it is usually noted that the duodenal deformity was present *without the presence of gastric hyperperistalsis*.

The frequent presence of pain, tenderness and a mass in the right upper quadrant, as well as high fever and leukocytosis, makes it almost impossible to differentiate acute pancreatitis from acute cholecystitis. However, a careful examination may reveal acute tenderness in the left upper quadrant, and while the serum amylase determination is being done, and gastric suction and intravenous hydration are being instituted, a gradual shifting of symptoms to the left side may occur. Even in the absence of a high serum amylase, a careful review of the history, especially if the pain usually tends to radiate to the left side, may arouse suspicion of pancreatitis. Under these conditions, conservative therapy under observation is justified even if the disease is actually acute cholecystitis.

When abdominal distention is the predominating symptom, a past history of recurrent attacks, the presence of fever and leukocytosis, and the absence of any obvious cause for intestinal obstruction, may make one suspicious of pancreatitis. The institution of intestinal tube suction and intravenous hydration while the serum amylase is being determined may change the clinical picture rapidly and the presence of acute tenderness in the epigastrium and left upper quadrant will make the diagnosis clear before the serum amylase is reported.

It is of the utmost importance to consider acute pancreatitis and determine serum amylase in all acute upper abdominal conditions, no matter how typical of other diseases the clinical picture may be.

Diagnosis in Interval Phase of Recurrent Acute Pancreatitis.—The patient who has had one or more undiagnosed attacks of severe upper abdominal pain due to pancreatitis will eventually enter a phase in which almost every large meal causes epigastric pain which frequently radiates to the left side, as well as to the right side and back. The outstanding characteristic is loss of weight due to fear of eating. The diagnosis is difficult owing to the absence of a high serum amylase level even during an attack which lasts two or three days. Normal x-ray findings of the organs of the upper abdomen are usual, although non-visualization of the gallbladder or the presence of gallstones is not infrequent. In this situation the secretin test is of great value. A diminished flow of pancreatic juice in response to a standard dose of secretin will confirm the diagnosis. Frequently, however, the secretin test falls within normal limits. Careful x-ray examination may reveal areas of calcification in the pancreas or close to the head of the pancreas. The

presence of a pancreatic cyst is also of diagnostic value. Expansion of the inner curve of the duodenum is suggestive of an enlarged head of the pancreas. A history that the gallbladder was not visualized by x-ray following an attack, but was found to visualize normally at a later date, is also suggestive of pancreatitis. A pericholecystic inflammation during and following an attack of pancreatitis will prevent normal function. As the exudate is absorbed, the ability of the gallbladder to fill and concentrate its contents will return.*

All these various considerations are of help in arriving at the diagnosis in the absence of high serum amylase or a diminished response of the pancreas to secretin. The secretin test may give a normal volume response, but the analysis of the pancreatic juice may show a diminished concentration of bicarbonate, or more important a very low concentration of amylase, which is indicative of pancreatic disease.

TREATMENT OF RECURRENT ACUTE PANCREATITIS

Treatment of the Acute Phase.—The treatment is nonoperative. There is no evidence that cholecystostomy or drainage of a necrotic pancreas is of any avail. The pancreas is so swollen that no bile can enter its ducts, and the damage has attained its maximum intensity. Necrotic tissue will not pass out along a drainage tube, and the trauma of the operative procedure in a dehydrated patient in shock is much more dangerous than any hypothetical benefit. The treatment is based on these principles:

1. Dehydration and shock are treated by intravenous fluids, blood and plasma.

2. Complete rest of the gastrointestinal system. Nothing is given by mouth. Gastric suction prevents acid from entering the duodenum; this inhibits the formation of the secretin which stimulates bile and pancreas juice flow. Atropine, 1.3 mg (1/150 gr.) every four hours, will also help to inhibit the function of the pancreas as well as the rest of the intestinal tract. It will also tend to relax the sphincter of Oddi. In addition, papaverine in doses of 120 mg (2 gr.) every four hours might be of help in relaxing the sphincter, but it must be remembered that a sphincter rendered spastic by inflammation and pain responds reluctantly to antispasmodic drugs.

3. Prevention of infection of necrotic tissue and exudate by the administration of large doses of penicillin, 300,000 units every six hours.

These three basic measures are invariably so effective that only small doses of demerol are needed to give the patient relief from pain. Mor-

* Also recently reported by Silvani and McCorkle (Ann Surg 127: 1207 [June] 1948)

phine should not be used since it increases the spasticity of the sphincter of Oddi for prolonged periods.

In addition to general measures, the urine should be examined for sugar, and the carbon dioxide combining power of the blood and the blood sugar level should be determined as emergency measures. The acidosis produced by a severe diabetes may require large doses of insulin. Injury to the kidney as evidenced by albumin and casts in the urine may require cautious administration of fluids to prevent water-logging in the lungs. As a rule, 3000 cc. of fluids, consisting of 1000 cc. of 5 per cent glucose-saline, 1000 cc. of 5 per cent glucose in distilled water and 1000 cc. of amigen, keeps the patient in adequate hydration and nutrition.

This treatment should be kept up *continuously* until the symptoms subside and the serum amylase (performed daily) has returned to normal. The gastric tube is then removed and clear fluids are given by mouth for twenty-four hours. If the symptoms do not recur, a soft diet (fat free) is given for two days and then a full fat-free diet. Any food containing fat, given during this period, may cause a recurrence of the pancreatitis.

When the patient has recovered and is walking about, the following examinations are advisable:

(a) X-ray of the stomach and duodenum.

(b) Glucose tolerance curve.

(c) Secretin test.

(d) X-ray of the gallbladder (Graham test) to determine its function as evidenced by filling and concentration of the dye; also to see if gallstones are present. A fat meal should never be given to contract and empty the gallbladder; this information is not sufficiently important to justify the risk of a recurrence of pancreatitis due to the fat meal. If the gallbladder is not visualized, the test should be repeated in two weeks function may return when the pericholecystitis has subsided.

(e) Examination of the blood for serum proteins, albumin-globulin ratio and prothrombin time.

Preoperative Management.—Operation is best performed three weeks after the attack when the inflammatory reaction has subsided. On the morning of the operation, a duodenal tube with a metallic bucket is passed and the patient is turned on the right side to facilitate passage of the tube into the duodenum. Preoperative medication should consist of demerol, 100 mg., and atropine, 0.40 mg. Morphine must not be given since it will interfere with the cholangiographic studies. General or spinal anesthesia may be used. A wooden funnel is placed under the patient on the operating table to facilitate insertion and removal of x-ray cassettes. A cannula is inserted preferably in an ankle vein for continuous intravenous infusions.

Operative Technic.—A high transverse abdominal incision is used, the right rectus being sectioned and the left rectus muscle retracted in thin individuals, and transection of both recti muscles in stout patients. The liver, gallbladder, stomach, duodenum and pancreas are carefully explored, as well as the rest of the abdomen. After adhesions are freed, the stomach is grasped firmly with a wet pack and pulled downwards and to the patient's left. A wet pack is then inserted in the foramen of Winslow to elevate the gastrohepatic omentum. The liver is gently retracted and the peritoneum over the gastrohepatic omentum is incised to expose the common duct from the superior edge of the duodenum upwards to the cystic duct. The cystic duct is dissected free and a thin strip of rubber tissue passed around it. At this point the metal olive tip of the duodenal tube is carefully placed in the second portion of the duodenum and cholangiographic studies are done. A 50 cc. syringe filled with 35 per cent water-soluble radiopaque solution is attached to a piece of rubber tubing about 18 inches long with a short large caliber (No. 18) needle at its end. The needle is inserted into the cystic duct which is steadied by traction on the rubber tissue around it. This maneuver also prevents any radiopaque fluid from entering the gallbladder. A 14 by 17 inch plate covered by a Lesholm grid is inserted under the patient and the x-ray tube is focused over the epigastrium. Meanwhile the anesthetist attaches a 10 cc. syringe, filled with N/10 hydrochloric acid, to the duodenal tube. The operator starts to inject the radiopaque material and begins to count slowly. At count 3, the acid is injected into the duodenum. At count 10 the anesthetist has stopped the respiratory movements of the patient, and simultaneously the x-ray film is exposed. It is important that the injection of radiopaque material be continued during the exposure of the x-ray plate. Another plate is taken immediately afterwards using the same technic, without more acid.

While the plates are being processed, the gallbladder is removed from below upwards and its bed closed over with interrupted silk sutures.

The plates are then examined for evidence of common duct stones and for proof of a common passageway as evidenced by visualization of the pancreatic duct (Fig. 152). Knowledge of the size, length, direction and tortuosity of the common duct visualized by the cholangiogram is of great help in passing instruments into the duodenum (Fig. 152).

The common duct is then opened, between sutures, just above the superior border of the duodenum. Any stones present are removed and a fine catheter is passed up towards the liver and 50 cc. of saline is washed through. The catheter is then directed downwards and saline injected slowly as it is pushed along. This maneuver sometimes helps to straighten the duct and relax the sphincter. If the catheter enters the duodenum, the common duct is palpated along its course for the pres-

ence of stones. The catheter is then removed and the sphincterotome* passed gently into the duodenum. The blade is then opened and the instrument is retracted until it hooks the papilla. The knife is closed and the instrument is withdrawn, thus performing the operation of endocholedochal sphincterotomy.

The common bile duct is then closed using fine interrupted silk sutures. A small tube is placed near this site, using one plain catgut suture to



Fig. 152.—Operative cholangiogram illustrating distortion of the common bile duct by long-standing pancreatitis which has resulted in calcific deposits throughout the gland. The tortuosity of the duct makes passage of an instrument through it difficult. Cholangiogram performed before any instrumentation will prevent injury.

hold it in place. The tube is brought out at the right end of the wound. A biopsy of the pancreas may then be taken. If there are any enlarged lymph nodes along the common duct, a not unusual occurrence in pancreatitis, one of them should be removed for histological examination. A pancreas that is enlarged and fibrosed by inflammation may also be

* Manufactured by the American Cystoscope Makers, New York City.

the seat of carcinomatous changes. The abdomen is then closed in three layers using interrupted silk sutures throughout.

Two difficulties frequently prevent section of the sphincter of Oddi through the common bile duct. First, the duct may be too narrow to allow the passage of the instrument, and again, the lower end of the common duct may be so tortuous and angulated that the sphincterotome cannot be passed without force. Under these circumstances, the anterior wall of the duodenum is opened, over a thin probe in the common duct if the duct is very narrow, or over the arrested tip of the instrument. The incision in the axis of the duodenal wall should be no longer than 3 cm. The sphincter is cut in one case over the probe for a distance of 1 cm, or if the instrument is found arrested at the ampulla of Vater, it can be manipulated through the papilla, the knife opened, and sphincterotomy performed under vision. The duodenum is then closed in the same direction as the incision, using a fine purse-string chromic catgut suture for inversion and several interrupted silk sutures for reinforcement.

Postoperative Care.—The duodenal tube is left in situ and suction continued for three days postoperatively. This is very important, since the swelling and edema at the sphincter from the operation and manipulation may cause pancreatitis unless the organs are put at rest by withholding of food and prevention of the entrance of gastric juice into the duodenum. The patient is supported by intravenous administration of glucose-saline, amigen and 5 per cent glucose in water. On the fourth day the tube is withdrawn and clear fluids are administered. A soft, fat-free diet is given on the fifth and sixth days, food being given every two hours, to keep up a continuous flow of bile and pancreatic juice. A full low-fat diet, with feedings every two hours, is then advised for the next five weeks. If necessary, sufficient bile salts to produce at least one bowel movement a day are administered with each meal. The patient is out of bed on the first postoperative day for a few minutes every four hours, and usually is able to walk about on the ward on the third day. The drainage tube is removed on the fourth day and the patient can be discharged on the fifth to seventh day.

In patients who are to be studied for proof that sphincterotomy (1) destroys the function of the sphincter, (2) prevents pancreatic reflux and (3) does not permit duodenal reflux by retaining the one-way valve action of the duodenal wall, a T-tube is placed into the common duct. A short, tightly fitting rubber cuff is then slipped over the T-tube at the level of the abdomen, and two safety pins are inserted into it. The T-tube itself must not be pierced. A strip of adhesive is then fastened to each pin and attached firmly to the skin, one across the abdomen and the other along the right flank. This holds the T-tube in a sling, prevents its accidental removal and, more important, prevents angulation of the

common duct due to the continuous pull of the drainage tube. The bile drainage is collected in a small bottle attached to the dressings. The drainage tube should never be attached to the bed since it tends to immobilize the patient and frequently causes the T-tube to be pulled out by accident. The T-tube can be tied off completely on the fourth day, since the bile tends to flow easily into the duodenum as a result of the sphincterotomy.

On the tenth day, a tube is passed into the duodenum, and cholangiographic studies are performed to test (1) the patency of the common duct, (2) the absence of reflux up the pancreatic duct following spasm produced by the injection of acid through the tube, and (3) the integrity of the duodenal wall (the mechanism that prevents duodenal reflux) as evidenced by the narrowing of the intramural portion of the common duct five minutes after the subcutaneous administration of 10 mg. of morphine. On the following day, a tube is passed again, and a kymographic tracing is made of the resistance to flow of saline through the common duct into the duodenum. The evidence of destruction of the sphincter is indicated by the absence of response to the intraduodenal instillation of acid, and the diminished response to the administration of morphine.

If the cholangiographic and kymographic studies indicate destruction of the sphincter of Oddi, the T-tube is removed and the patient discharged. The fistula closes immediately because resistance to flow of bile into the duodenum is minimal.

ILLUSTRATIVE CASES

The following abstracts of case reports are illustrative of principles which have been discussed:

CASE I.—O. T. (Bellevue Hospital, No. 12709-47) was a 44 year old male kitchen chef who, for a number of years, worked sporadically during intervals between alcoholic sprees. For the three years prior to admission these bouts frequently ended in attacks of severe abdominal pain, distention and vomiting. He was admitted to different hospitals on these occasions and at one he was advised to have an operation for a perforated peptic ulcer. He refused operation and subsequently recovered. In March, 1946 he was admitted to Bellevue Hospital with the usual complaints of severe epigastric and right abdominal pain, fever, distention and vomiting. Serial blood amylase determinations at this time established the diagnosis of acute pancreatitis. X-ray examination of the gallbladder, stomach and duodenum revealed no abnormalities. He left the hospital after the attack subsided and was readmitted several times between March, 1946 and January, 1947 with similar episodes. At this time operation was agreed upon and on February 1, 1947 it was performed. There were dense adhesions about the gallbladder, liver and adjacent organs. The pancreas was

firm; the common duct normal. An operative cholangiogram visualized the entire pancreatic duct (Fig. 153). The gallbladder was removed and the sphincter of Oddi was sectioned. Postoperative cholangiograms after two weeks failed to visualize the pancreatic duct (Fig. 154). After administration of morphine the function of the intact duodenal wall as a valve to prevent further duodenal reflux could be demonstrated (Fig. 155). Kymographic studies were further evidence of destruction of the sphincter of Oddi.



Fig. 153 (Case I)—Operative cholangiogram performed while N/10 hydrochloric acid was applied to the sphincter of Oddi, thus inducing spasm. The radiopaque solution was forced through the pancreatic duct system, proving the presence of a biliary pancreatic passageway.

The patient has been readmitted to the hospital for alcoholism several times since operation—the last admission being in September of 1948 and on no occasion has there been a recurrence of the abdominal pain.

This patient illustrates acute pancreatitis recurring in an alcoholic. The diagnosis was proved by serial amylase determinations and the reflux mechanism demonstrated by operative cholangiograms. For one year and seven months following operation the patient has had no recurrence and has been observed in the hospital while recovering from several alcoholic sprees.

CASE II.—D. R. W. (Beth Israel Hospital, Newark, N. J.—operation with Dr. A. Abrams) was a 40 year old white man with a history for twelve years of attacks of severe epigastric pain radiating to the back and to both upper quadrants and accompanied by vomiting. The attacks would last from two hours to two days and initially recurred about every six months, but in recent years were coming every few weeks and there was some pain after every meal. On one occasion ten years previously a diagnosis of perforated peptic ulcer was made but no operation was performed. Between 1940 and 1944 he was admitted to four different military hospitals where repeated x-rays of the gallbladder



Fig. 154. (Case I) —Cholangiogram performed through a tube two weeks after operation. The pancreatic duct is not visualized.

stomach and duodenum were normal. He was finally discharged from the army on February 11, 1948 because of his incapacitating pain. No diagnosis was made. Following his discharge, further x-rays revealed calcification of the pancreas (Fig. 156). An operation was advised by his physician and a cholecystostomy was done. The patient refused permission for a pancreatectomy. His pain was relieved so long as the cholecystostomy tube drained. When the tube was removed the pain promptly returned. On April 12, 1948 a secretin test revealed marked impairment of the pancreatic function (total volume 120 cc.; total amylase 65 units). On April 16, 1948 he was again operated upon and a cholangiogram (Fig. 157) was taken. The pancreas was large, hard and knobby. The sphincter

of Oddi was sectioned through the common duct. The patient has been symptom-free since operation

This patient illustrates the long history of undiagnosed pain with eventual development of calcified pancreas. Operation has provided complete relief of pain in spite of the presence of the calcified pancreas



Fig. 155. (Case I) —Cholangiogram performed through a T-tube two weeks after operation and after the administration of morphine. The contraction of the duodenal wall, which is the mechanism preventing reflux of duodenal contents into the biliary tract, is illustrated

CASE III —J. S. (Bellevue Hospital, No 18966-47) was a 57 year old white man with a history for nine years of recurrent attacks of severe epigastric pain radiating to the back and both scapulae. These attacks were accompanied by vomiting and distention and lasted from two to seven days. Eight years prior to his most recent admission, in 1939, a cholecystectomy was performed on the Third Surgical Division of Bellevue Hospital for these complaints. The diagnosis was chronic noncalculous cholecystitis. His postoperative course at this time was complicated by a dehiscence of the abdominal wound on the third postoperative day. The wound was resutured and he recovered to be discharged

to the outpatient department. He returned frequently with persistent complaints of abdominal pain unchanged by operation.

The patient was readmitted to the hospital in April of 1947. Repeated serum amylase determinations were done and were persistently low, never rising above 50 mg. per 100 cc. The secretin test revealed normal pancreatic function. Operation was performed on May 29, 1947 at which time a cholangiogram demonstrated the pancreatic duct after spasm had been induced in the sphincter of Oddi by the application of hydrochloric acid. There were extensive adhesions in



Fig 156 (Case II).—X-ray film of calcified pancreas

the right upper quadrant and the common duct was narrowed. The sphincter of Oddi was sectioned under direct vision through an incision in the duodenum. His postoperative course was again complicated by wound dehiscence and, further, a biliary fistula. After a delayed convalescence he was discharged with the fistula closed and wound healed. The patient was re-examined one year later. He had gained 50 pounds in weight, was working steadily and has had no pain whatever on a full, varied diet.

This patient illustrates pancreatitis without positive findings and diagnosis by exclusion. His complete rehabilitation is verification of the diagnosis and of the effectiveness of the operation.

of Oddi was sectioned through the common duct. The patient has been symptom-free since operation.

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CASE IV.—K. R. (Bellevue Hospital, No. 7790-48) was a 29 year old female secretary with a history of six years of recurrent attacks of midabdominal pain radiating to the epigastrium and both upper quadrants. X-rays of her gall-bladder and gastrointestinal tract showed no abnormality. In 1943, during a particularly severe attack, an emergency abdominal operation was performed at another hospital. A diagnosis of acute pancreatitis was established. A drain was placed to the pancreas and a cholecystostomy performed. Drainage from the cholecystostomy site persisted intermittently for five years and at one time a small cholesterol stone was extruded. When the fistula was closed the attacks of abdominal pain recurred. She was admitted to Bellevue Hospital on February 15, 1948. The secretin test showed a marked reduction in pancreatic secretion (total volume 42 cc.; total amylase 43 units). At operation on February 25, 1948 the common bile duct was found markedly dilated, the pancreas was hard and enlarged, a cholangiogram demonstrated the whole of the pancreatic duct (Fig. 158). Cholecystectomy and section of the sphincter of Oddi were carried out.

This patient was seen in September of 1948, seven months after operation, and she has been entirely free of symptoms. Her fistula is closed.

This case illustrates the diagnosis of acute pancreatitis by exploratory operation and persistence of symptoms after simple drainage and cholecystostomy.

COMMENT

We were able to demonstrate a common passageway in the majority of cases of recurrent pancreatitis. The fact that these patients were cured of their attacks by sphincterotomy is evidence that reflux of bile is the etiological factor. There is no doubt that there are other causes of pancreatitis. Mumps is a proven example. Viruses, such as those affecting the liver in infectious hepatitis, may possibly cause pancreatitis. Alcohol may have a specific action on the pancreas, but in our experience the attacks following alcoholic sprees occurred in patients with a common passageway; in addition, the clinical picture did not vary from that occurring in patients who did not drink alcohol.

The following fundamental problem remains to be solved. Granted that an individual with spasm of the sphincter of Oddi has a common passageway, how is it possible for bile to enter the pancreatic duct, since we know that, following a meal, the secretory pressures of the bile and pancreatic juice are equal? It must mean that in these individuals bile is discharged into the duct systems before pancreatic juice secretion starts. Either the secretin which stimulates the pancreatic juice formation is not produced, or it is destroyed excessively in its transport through the blood stream by secretinase. A third possibility exists: secretin produced in large amounts may inhibit the pancreas.²⁷

The question is raised: Can the sphincter of Oddi, when sectioned, regain its function by the process of healing? Comparison is often made with the anal sphincter which is known to heal after it is cut. But it must be remembered that the whole anal sphincter is rarely sectioned and that, when it is completely sectioned, it remains permanently incontinent. Finally, experimental and clinical observations have shown that following section of the sphincter of Oddi by the sphincterotome, the circular muscle retracts and heals in the position of retraction.²⁶

Reflux of duodenal contents into the biliary tract with resulting cholangitis is prevented by the preservation of an intact duodenal wall musculature. It can be demonstrated by cholangiographic studies³ that the common bile duct in its oblique passage through the duodenal wall is effectively closed during contraction of the duodenal wall. Thus a one-way valve effect, permitting bile to flow into the relaxed duodenum and closing the duct during contraction of the duodenum, is preserved. There have been no instances of cholangitis following section of the sphincter in twenty-eight cases.

The most difficult problem in the treatment of pancreatitis is in those patients who have no objective evidence of the disease. Under observation, an elevated serum amylase cannot be found, even during acute attacks; the secretin test shows normal pancreatic function; and all x-ray examinations are normal. In spite of this, these persons have almost daily attacks of postprandial pain, with marked loss in weight due to fear of eating. Every few days or weeks a severe attack occurs, lasting one to three days, and is followed by a period of epigastric and left upper quadrant tenderness. Great caution must be exercised both in diagnosis and treatment. These patients are usually highly emotional and react not only by the spasm of the sphincter of Oddi, but also by the spasm of the pharynx, cardiac sphincter, pylorus, small and large intestine, and even of the urinary bladder. It is true that sphincterotomy will relieve them of their postprandial biliary and pancreatic pain and will prevent pancreatitis, but their continued emotional disturbance will lead to symptoms from other parts of the intestinal tract. We have sectioned the sphincter of Oddi in some of these patients, often with spectacular results, but some of them have had recurrences of pain from other parts of the intestinal tract. It is possible that better results may be obtained by periesophageal vagotomy. However, further observation of these patients and the use of psychotherapy and antispasmodic drugs will be required before any definite operative procedure can be recommended.

SUMMARY AND CONCLUSIONS

Pancreatitis is a common disease of varying intensity from mild attacks to severe abdominal catastrophies. It is frequently associated with biliary tract disease and many patients with conditions diagnosed as postcholecystectomy syndrome, biliary dyskinesia and the like are actually suffering from recurrent pancreatitis.

Reflux of bile into the pancreas is a predominating etiological factor. This reflux is frequently produced by abnormal spasm of the sphincter of Oddi in the presence of a common biliary pancreatic passageway above the sphincter. Surgical destruction of this muscle will prevent further attacks of pancreatitis. The intact duodenal wall prevents reflux of duodenal contents into the biliary tract in the absence of the sphincter.

Illustrative cases are cited.

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or jaundice and quickly became inoperable. It was observed also that in such cases perforation of the gallbladder in acute cholecystitis occurred rapidly and with little attempt at peritoneal protection. Unless quickly relieved by surgery, the tense gallbladder early showed gangrenous changes, and when it perforated a rapidly spreading and almost invariably fatal peritonitis resulted.

Thus delay in diagnosis was dangerous, but equally dangerous was delay for any other reason that might postpone surgical relief of either acute cholecystitis or common duct occlusion. Such delay might understandably occur in an endeavor to improve the patient's condition to withstand operation. Here an exercise of judgment was required to determine at what point the surgeon's efforts to improve his patient's condition, desirable as such measures might be,² began to work to the patient's disadvantage in unduly delaying surgical relief. Such urgent situations allowed no time for the correction of incidental or underlying disease or deficiencies. In the case cited above it was not even possible, in the presence of acute sepsis, to bring the patient's diabetes again under control. Nothing, of course, could be done at the moment for her arteriosclerosis or for the intercurrent pyelitis. The most one could safely and reasonably hope to accomplish was to replace fluid and electrolyte loss, provide blood for transfusion, empty the bowels by enema and the stomach by aspiration (incidentally leaving the tube in place at least during the operation), give a protective dose of penicillin (250,000 U), and proceed with surgery. This was the procedure adopted; and it was the plan generally followed with patients in this group where urgent surgery was demanded.

Choice of Anesthetic.—With this meager but necessary preparation accomplished, the next question arising in such cases was the choice of appropriate anesthetic. Contrary to expectation, the use of general anesthesia in these bad risk patients was not attended with the extreme hazard we had apprehended.³ There was, in fact, no anesthetic death in any of our cases of biliary tract emergencies, and only one (spinal—aspiration of vomitus) in the total group of urgent cases. We came to believe that a general anesthetic, well chosen and skilfully administered, presented a relatively minor risk in these cases.⁴ With respect to the incidence of postoperative pneumonia, there was virtually no difference between the various anesthetic agents employed.⁵ In fact, we gained the impression that the anesthetic itself was not a significant factor in the production of pneumonia, inasmuch as over 50 per cent of the cases in which this complication appeared developed the disease ten days or more after the operation. Of the various available methods of anesthesia, we have come to favor cyclopropane for these bad risk patients. It provides low toxicity, ready induction, good relaxation, full oxygenation throughout

and rapid recovery. Combined with intocostin, as it has been in our later cases, the same results are safely achieved with minimal quantities of the gas.

Selection of Operation.—In the case under consideration, we elected cholecystostomy as the operation of choice. The reason for this selection will be apparent from a review of our experience with problems of this type, as revealed in our original study of thirty-four cases of biliary tract emergency, as well as from the results obtained in subsequent cases.

One of the principles originally laid down for the management of emergency situations in elderly bad risk patients was to perform *the least formidable surgical procedure that would meet the immediate need for relief and save life*. This principle we adhered to in dealing with the earlier patients covered by our study. Later we became convinced by the arguments propounded by many surgeons in favor of cholecystectomy. We were the more readily persuaded to change our tactics because our early mortality was high (the want of antibiotics in about the first half of our reported thirty-four cases may have been a factor in this), and because of the ease with which the acutely inflamed gall-bladder might be removed. It was only after a critical analysis of the entire group of thirty-four cases that we recognized the defects of this commonly accepted practice as applied to patients of this type and reverted to our original plan.

The emergencies caused by disease of the biliary tract in this group were of two varieties. One consisted of occlusion of the common duct (fifteen cases), with rapidly advancing jaundice. In six of these, acute cholecystitis was also present. Exploration of the common duct with T-tube drainage alone was done in two cases, and common duct drainage with cholecystostomy in three. All five patients died. Cholecystostomy alone was done three times for obstructive jaundice with one recovery. Cholecystgastrostomy was performed twice for obstructing cancer with one death and one early survival. Common duct drainage with cholecystectomy was done five times, with three deaths and two successful results. The severity of this emergency may be judged from the fact that of fifteen patients presenting obstructive jaundice, eleven failed to survive. These operations were performed, on the average, about the tenth day from the onset. This lapse of time represents the delay incidental to attempts to establish the correct diagnosis and to bring the patient into optimum operable condition. There is no doubt that some would have benefited from earlier intervention.

The other type of emergency, acute cholecystitis uncomplicated by obstruction of the common duct, was represented by nineteen cases. Cholecystostomy with drainage was done in ten, with four recoveries and six deaths. Two of the deaths were due to peritonitis which was

present at the time of operation, resulting from early perforation of the gallbladder. Cholecystectomy was performed in the remaining nine, with five recoveries and four deaths. Two of these deaths also resulted from peritonitis due to perforations found at operation. The third day after onset was the average time for the performance of these operations. The presence of seven perforations in nineteen cases (four of them occurring within forty-eight hours of the onset of symptoms) emphasizes the importance of early intervention, particularly in patients of this type.

Since, in acute cholecystitis, cholecystostomy showed a mortality of 66 per cent as against 44 per cent in those cases where cholecystectomy was done, it would seem to be the logical inference that cholecystectomy is the preferred procedure. There were, however, certain other factors involved which served to modify this conclusion. The figures fail to take into account the individual patient's age, general condition and coincidental ailments. In most instances in which cholecystostomy was done during this period, it was adopted because the surgeon, owing to the patient's condition, did not dare to perform the preferred cholecystectomy. In the presence of established peritonitis from perforation, both procedures were equally ineffective in saving the patients.

As will be seen in Table 1, the over-all mortality rate in the group of urgent biliary tract cases was 62 per cent. Although the average day of death postoperatively was the twenty-fifth, and fourteen of the twenty-one fatalities resulted from incidental conditions not directly related to the disease for which operation was performed, we have chosen to include in the postoperative mortality any death that occurred while the patient was still under our observation and control. Seven deaths (four from peritonitis, one each from parotitis, liver abscess and gas bacillus septicemia) attributable to the disease represent the largest group of fatalities. Pneumonia (six) and cardiac failure or coronary occlusion (six), some of which cases occurred early and some late, together were responsible for more than half of the deaths. Cardiac failure, coronary infarction, cerebral hemorrhage and other accidents reflecting pre-existing or intercurrent disease, must be anticipated and reckoned with in dealing with patients of this type. Together they argue for the desirability of prompt and rapid surgical relief and the employment of the least traumatic procedure that will meet the emergency.⁶

Conclusions Drawn from Study.—The completion of this study left us profoundly dissatisfied with the results of urgent surgery on the biliary system in patients in this age group. Granted that the mortality rate was, as we had found, influenced largely by the patient's pre-existing ailments, it was nevertheless felt that improvement should be sought. To this end we returned to the policy, originally enunciated, of doing no

more surgery in the face of an acute emergency than was demanded to relieve the situation and save life. This policy has since been adhered to even in those patients whose condition seemed relatively good, and even when it seemed likely that a secondary operation might be needed to remove the basic difficulty.

In practical terms this meant the employment of simple cholecystostomy, the removal of stones from the gallbladder, and the institution of

TABLE 1
ACUTE CHOLECYSTITIS AND COMMON DUCT OBSTRUCTION
Cases: 34 Average Age: 73
(Minimum: 61 Maximum: 91)

Preoperative Condition		Anesthesia	
Arteriosclerosis . . .	27	Cyclopropane	22
Arteriosclerotic heart disease	19	Local	11
Diabetes	1	(Local with pentothal, 1)	
Pyelonephritis . .	3	Ether	1
Nephritis . . .	14		
Cerebral accident	3	Cause of Death	
Coronary accident	3	Peritonitis	4
Valvular heart disease	1	Pneumonia	6
Tuberculosis (miliary)	1	Cardiac failure or coronary	6
Neurosyphilis . . .	1	Cerebral accident	1
Amyotrophic lateral sclerosis . . .	1	Other causes	
Paralysis agitans . . .	1	Parotitis	1
Operative Condition		Liver abscesses	1
Cholecystitis	19	Gas bacillus septicemia	1
(Perforated or gangrenous, 7)		Septic fractured hip (pinned)	1
Obstructed common duct . .	15	(Late deaths carcinoma, 4)	
(6 with cholecystitis)		Result	
Biliary carcinoma	5	Recovered	13
Biliary stone	10	Died	21
Day of Operation		Total mortality rate	62%
Cholecystitis (av)	3	Cholecystitis	50%
Obstructed duct (av)	10	Obstructed duct	73%

drainage where this procedure would suffice to relieve a hydrops of the gallbladder, an acute suppurative cholecystitis or an acute jaundice from obstruction in the common duct. This policy was followed even when the removal of the gallbladder appeared temptingly easy, for we believed that even a technically simple cholecystectomy added appreciably to the risk. For the gallbladder that showed beginning gangrenous changes, drainage into it and outside it was supplied. Where, in obstructive jaundice, a cholecystostomy produced a free flow of bile through the cystic duct, no more was done. When this flow did not occur, the common duct was drained as well, and, if readily available, an obstructing

stone removed. The gallbladder was, in such instances, not extirpated. As before, all possible measures of preparation, support and prophylaxis were invoked in the patient's aid and efforts were renewed to insure early operative intervention.

Our plan of postoperative treatment was not essentially modified. This consisted in the employment of oxygen for six hours or more after operation, the use of transfusions, fluids administered preferably by hypodermoclysis to avoid overloading the circulation, the sparing use of salt and of depressing narcotics and the liberal administration of antibiotics, vitamins and protein hydrolysates. Such patients were taken out of bed usually on the day following operation, and when they could do so, were encouraged to walk a few steps.

Results Since Readoption of Principle of Performing the Least Formidable Surgical Procedure That Will Meet Immediate Needs.—Since the readoption of this plan, there have been seven patients on our service who fulfilled these criteria. Their average age was 74, the oldest being 89. They suffered from the diseases of deterioration characteristic of this group. Prominent among these were arteriosclerotic heart disease, hypertension, nephritis and obesity. One, the patient whose case has been cited, was diabetic and had had an amputation.

The surgical diagnosis of acute cholecystitis with cholelithiasis was made in all and operation performed early. In one there was an associated acute cholangitis and one patient had a stone impacted in the common duct (both were acutely jaundiced). Two were noted as having empyema of the gallbladder. None of the gallbladders had perforated, though one was partially gangrenous.

In each case cholecystostomy was performed, with removal of stones from the gallbladder and institution of drainage. In one case an impacted stone was removed from the common duct as well, and a T-tube inserted.

Postoperatively one patient suffered a partial wound dehiscence, one developed atelectasis, and another bronchopneumonia. All seven patients recovered and the fistulas healed in all but two. The patient whose case we have described was one of these. The other was operated upon, after careful and leisurely preparation, some six weeks later under far more favorable circumstances than those attending the acute emergency. A necessary cholecystectomy was performed and uneventful recovery followed.

It is of interest to note that one of these patients, 79 years of age, had had a cholecystostomy for a similar episode one year previously. Also of interest is the fact that during the period immediately preceding our change of policy, four patients, 65 years of age or over, were subjected to cholecystectomy for acute cholecystitis, and three died.

orders amenable to surgery. Fundamentals are never to be shunned, and a careful history and physical examination of the patient are the starting point in any diagnostic work-up. Certain clues will thereby be established. Lymph node enlargement may immediately suggest biopsy and thus early diagnosis. Inspection of the sclerae may show the pingueculae associated with Gaucher's disease or the mild icterus of a cirrhosis or hemolytic anemia. Petechiae may suggest an hemorrhagic diathesis.

We have found the subsequent outline useful in the systematic study of conditions involving the spleen.

1. History and physical examination
2. Blood studies
 - a. Complete blood count, including platelet determination; red cell fragility test, smears for spherical microcytes; sedimentation rate, Coombs test; Kahn or Mazzini test
 - b. Bleeding, clotting times, and prothrombin time
3. Tissue biopsy (skin, bone marrow, lymph node, liver, spleen)
4. X-ray studies (as indicated)
 - a. Esophagram for varices
 - b. Gastrointestinal series
 - c. Barium enema
 - d. Intravenous pyelogram
 - e. Flat film of the abdomen
 - f. Bones
5. Liver function tests
 - a. Bromsulfalein test
 - b. Hanger (cephalin flocculation) test
 - c. Serum protein determination (albumin, globulin)
 - d. Serum phosphatase
 - e. Serum bilirubin
6. Miscellaneous
 - a. Capillary fragility test
 - b. Mantoux test
 - c. Blood chemistry (other than above if indicated)

CONDITIONS IN WHICH SPLENECTOMY IS INDICATED

Adjunct to Other Surgery.—In surgical therapy involving organs contiguous with the spleen, it is often mandatory to do a splenectomy. Carcinomas of the stomach, adjacent colon or pancreas often require such a procedure along with removal of the primary growth. Pancreatic resection in hyperinsulinism may so compromise the splenic vein that removal of the spleen is inevitable.

Anomalies.—The usual splenic attachments are such that very little motion of the spleen takes place. Rarely as a result of developmental anomalies an unusually long pedicle is formed. A so-called mobile spleen

may then be encountered. Varying degrees of pain may follow due to drag on, or torsion of, the pedicle. Repeated "attacks" may recur over a period of time or a single irreducible torsion may precipitate a vascular occlusion and massive infarction of the spleen. The first situation calls for elective operation whereas the latter is a surgical emergency.

Rupture.—Rupture of the spleen may be either traumatic or as a spontaneous incident unrelated to any form of trauma. The traumatic form may be the result of direct violence or "contrecoup." Furthermore, the injury may be associated with an open communicating wound of chest or abdomen. Traumatic or so-called subcutaneous rupture of the spleen may present single or multiple lacerations of pulp substance, and in severe cases damage to the hilar vessels. With the exception of avulsion of the pedicle, McIndoe's classification of splenic tears summarizes the variations encountered: (1) minor superficial capsular rupture or slight splenic contusion producing parenchymal ecchymosis; (2) intra-splenic hematoma and subcapsular hemorrhage without capsular rupture; (3) capsular and parenchymal rupture with perisplenic hematoma.

The splenic rupture, of course, may be complicated by multiple injuries involving other viscera. Prompt splenectomy of the ruptured spleen carries little or no mortality. With associated injuries to other organs, the mortality jumps alarmingly.

Spontaneous rupture of the spleen is a rare occurrence that merits comment. As the expression implies, rupture occurs without trauma, i.e., spontaneously. In most instances, the spontaneous rupture develops in an already diseased organ. Malarial spleens, and the infarcted spleen in subacute bacterial endocarditis, have been known to rupture spontaneously. Spontaneous rupture, however, is a potential threat in any form of splenomegaly. In either type of rupture, pain, tenderness and muscle spasm in the left hypochondrium, together with the classical symptoms and signs of intra-abdominal hemorrhage, should suggest the diagnosis. However, the symptoms and signs are occasionally masked in certain cases. The oft-described "latent period of Baudet" is a clinical variant peculiar to some splenic ruptures. Following severe trauma and early shock the patient apparently quickly responds to shock therapy. One may thereby be lulled into a feeling of security. Following a varying period of well-being, the patient again suddenly slips into a state of profound shock for the second time. Failure to check blood pressure and pulse at frequent intervals may result in this catastrophe. Small capsular tears with initial hemorrhage and then clot tamponade will produce the picture. Likewise, subcapsular hemorrhage with moderate blood loss contained within a ballooning capsule and later break-through of the overdistended "bag of blood" has also been described as a mechanism. A side wall tear of the major artery or vein or complete avulsion of the

pedicle will promptly declare itself in terms of massive intraabdominal bleeding.

Complete splenectomy is still the only safe therapy. The use of oxidized gauze, gelfoam or similar materials is, in the author's opinion, unsafe in the light of our present experience, in the peculiar vascular and soft, spongy tissue of the spleen.

Hemolytic Icterus.—The clinical and hematological manifestation of hemolytic or acholuric jaundice has been the source of much discussion and controversy over a period of years. This confusion in the minds of our medical colleagues has unfortunately been transmitted into varying results following splenectomy if certain rigid standards are not adhered to

In this country it is now a quite generally accepted dictum that there are two types of hemolytic icterus: (1) congenital hemolytic icterus and (2) acquired hemolytic icterus

Congenital Form.—The congenital form was first described by Minkowski. A strong familial history is usually elicited and there is common agreement that the condition is transmitted as a mendelian dominant character. Certain clinical and hematological features must also be present to classify a case in the congenital group. Clinical signs include transient mild, to severe, icterus, varying degrees of anemia, and splenomegaly. In its milder forms the disease is often never recognized. With severe hemolytic crises profound anemia, pyrexia and prostration are the rule. Unchecked by transfusion or splenectomy, a severe hemolytic crisis may rapidly progress to death. Blood studies in the congenital form will reveal, besides the anemia, increased fragility of the red cells to hypotonic saline, reticulocytosis and usually the presence of spherical microcytes in varying percentages. The leukocytic series remains unchanged and the thrombocyte count is normal. Given all the foregoing factors one can with reasonable assurance make a diagnosis of congenital hemolytic icterus. Unfortunately, however, this ideal is not always encountered

The most difficult and disturbing cases are those in which all these criteria are not present. Reference is made to those cases in which no familial history can be elicited and in which the patients are extremely ill, showing evidence of marked hemolytic activity, with few or no spherocytes and little increase in the red cell fragility. This type of case poses a serious decision for the surgeon. A few years back it would have been extremely difficult to differentiate this latter type of case from the acquired form. Believing it was the latter, and knowing the brilliant results of splenectomy in congenital hemolytic jaundice, and contrariwise, the generally poor results in acquired hemolytic icterus, the surgeon might well have decided to avoid surgery and thereby probably lose the patient.

Recently, we have come to place great reliance on the use of a new

diagnostic test first described by Coombs. This investigator found that in cases of acquired hemolytic icterus a suspension of the patient's cells when mixed with diluted antihuman rabbit serum would produce macroscopic agglutination of the patient's cells after one hour. This he called a "positive test" that is indicative of acquired hemolytic icterus. Failure to produce agglutination of the patient's red cells was called a "negative test" and was indicative of congenital hemolytic icterus.

These initial observations have been confirmed by Boorman, who found the test consistently accurate in a reasonably large series of cases in both the congenital and acquired category.

We, likewise, in a limited number of our own cases, have found it regularly trustworthy. The value of such a test may be judged from the following examples.

Within the past two years we have had two cases of hemolytic jaundice in infants under two years of age. In the first, a boy of six weeks had a proven familial history of the disease and a severe hemolytic anemia was present, but a fragility test bordered on the normal. Response to transfusions had been lacking and his blood was hemolyzing faster than it could be administered. The Coombs test proved negative. With the diagnosis of congenital hemolytic icterus thus supported, a splenectomy was done with every expectation of cure, and he had prompt cessation of hemolytic activity.

Shortly afterwards, a two months' old male infant was studied with an almost identical blood picture and clinical course. However, no familial history was obtainable and the Coombs test was positive. A diagnosis of acquired hemolytic icterus was made. Again, transfusions and medical management developed into a losing game. As a last resort, splenectomy was decided upon, knowing full well that the prognosis in the so-called acquired hemolytic icterus is poor in most cases. The infant survived operation and the result has been one of diminished hemolytic activity requiring only periodic transfusions. Although *this proved life-saving*, it by no means approaches the dramatic and practically 100 per cent cure rate in congenital hemolytic icterus.

The outline in Table 1 has proved a useful guide to us in differentiating cases of congenital from acquired acholuric jaundice.

Not infrequently hemolytic jaundice is complicated by the coexistence of calculous disease of the biliary tract. As a result of prolonged hemolytic activity, pure pigment stones are often formed. This incidence of gallstones in hemolytic jaundice has variously been reported as between 50 and 75 per cent of all cases. The characteristic clinical picture of biliary tract disease may then be superimposed on the already active hemolytic jaundice. Cholecystogram will usually confirm the diagnosis and cholecystectomy with or without common duct exploration may have to be carried out. Routine cholecystectomy can be performed at the same time as splenectomy if the patient's condition warrants it. This is

easily done through a long transverse upper abdominal incision. If the patient is greatly depleted as the result of acute severe hemolytic activity, splenectomy had better be done first and cholecystectomy at a later date.

Ever since Lord Dawson of Penn gave his memorable report on the efficacy of splenectomy in congenital hemolytic icterus, it has been universally recorded that a prompt and permanent remission will follow splenectomy in nearly 100 per cent of these cases. It is of interest that we have witnessed the onset of first symptoms in this disease as early as six weeks of age and as late as the sixth decade of life. Although a few rare cases of failure to cure have been reported, these have occurred only in instances in which splenic tissue has been retained by the host, either

TABLE 1
DIFFERENTIATION OF CONGENITAL AND ACQUIRED ACHOLURIC JAUNDICE

	Congenital Hemolytic Icterus	Acquired Hemolytic Icterus
Familial history	Usually present	Absent (except in rare instances)
Splenomegaly	Present	Present
Hemoglobin and red blood cells	Anemia	Anemia
Reticulocytes	Slight to marked elevation	Slight to marked elevation
Serum bilirubin	Elevated	Elevated
Spherical microcytes	Usually a prominent feature	Not prominent, often absent
Red cell fragility	Usually increased	Usually normal
Coombs test	Negative	Positive
Associated primary cause (e.g., infections, drugs, lymphosarcoma, Hodgkin's disease)	Not present	Often present, as basic lesion

in the form of accessory spleens, or in such a bizarre occurrence as a coexisting abdominal teratoma with splenic tissue. Failure to obtain a reversal of the hemolytic process should immediately prompt the surgeon to suspect the existence of retained splenic tissue. Of further concern to the surgeon is the possibility of seeding peritoneal implants by rough handling and tearing of the splenic capsule during surgery. Splenic tissue has a surprising predilection to carry on an almost saprophytic existence, if it is spilled over peritoneal surfaces. This has been described as a not infrequent sequel in traumatic rupture of the spleen. It is easy to understand how compensatory hyperplasia of new splenic implants might occur in such diseases as hemolytic icterus or purpura haemorrhagica, with resulting clinical failure.

Acquired Form.—In acquired hemolytic icterus, the role of surgery

is much more limited. A primary cause should be searched for in every instance, such as an infectious process, drug idiosyncrasy, lymphosarcoma, Hodgkin's disease and Cooley's anemia. Whenever the primary mechanism can be controlled, as in infection or drug sensitivity, indicated steps should be taken. Whether the hemolytic process be idiopathic or secondary, transfusion is the sustaining treatment we must constantly rely upon. When, in spite of repeated transfusions it becomes impossible to maintain an adequate blood level, then splenectomy must often be considered as the hope of last resort. Our experience has been generally disappointing in this group. Surgery offers very little more than a 15 per cent chance of arrest of the hemolytic activity, with 85 per cent unaffected by removal of the spleen. Surprises are of sufficient frequency, however, for the surgeon to continue to adopt a watchful and critical attitude towards these cases. The succeeding section on hypersplenism is pertinent to this discussion and we shall accordingly defer further comment until that point.

Certain additional points in the management of these cases of hemolytic icterus are worthy of note. As far as possible, transfusion is withheld in the twenty-four to forty-eight hour period immediately preceding surgery, as in some cases transfusion may precipitate a severe hemolytic crisis at or about the time of operation. If possible, blood is withheld during this operative phase until just after the splenic artery is clamped. Blood can then be given with little risk.

During the postoperative period we have found that frequent reticulocyte counts, along with serum bilirubin determinations, provide an accurate index of the rate of clinical improvement.

Idiopathic Purpura Haemorrhagica.—Singularity enough, few advances in our knowledge of the etiology and management of this condition have developed in the past decade. Its pathogenesis still remains obscure, although the proponents of "hypersplenism" believe that the spleen exercises a primary role in selective sequestration of the thrombocytes.

The diagnostic features so prominent in this disease have been frequently and amply established in medical literature. The disease, besides being "idiopathic," occurs in acute and chronic forms. It is characterized by a tendency to bleed from skin, mucous membranes, or into connective tissue or any viscus. Petechiae, purpuric spots, and gum bleeding are visible clues. Internal bleeding into viscera can give protean signs and symptoms depending on the site and organ involved.

Besides the secondary type of anemia, the dominant blood features are the quantitative reduction of platelets and prolonged bleeding time. In addition, some believe that increased capillary permeability also adds to the hemorrhagic tendency.

The chronic forms of the disease usually offer little difficulty in diagnosis. It must be "idiopathic," not secondary to infection, pyogenic or tuberculosis. Drugs and poisons must be ruled out. The primary anemias, leukemias and aplastic anemia should be carefully excluded by blood count, blood smears and sternal marrow biopsy. In the chronic forms, time allows for repeated blood studies and thereby reinforcement of clinical impression.

The acute fulminating forms of purpura often prove the most difficult to diagnose. Not infrequently, the severity and speed of the process precludes prolonged diagnostic study. In these cases, repeated blood transfusions often fail to hold the dike and an emergency splenectomy must be accepted as a life-saving resort. This will give dramatic results in most cases, be they in the typical idiopathic group or even in those purpuras secondary to drugs, toxin or infections.

Elliott's interesting studies have shown the equal sex distribution in childhood and the female dominance during adolescence, puberty and adult life. Spontaneous remissions are the rule in childhood but occasionally a fulminating case occurs in this group, uncontrolled by transfusion. Splenectomy then must be resorted to to save life or prevent fatal blood loss or irreparable damage to brain, retina or kidney.

In the second decade, spontaneous remissions are unusual and, in cases of active bleeding, splenectomy can be predicted to give a complete arrest of the bleeding tendency in 90 per cent or more of the cases. As Elliott has shown, the medical control of this group offers no such comparable results. The operative mortality in a series of over sixty-three cases from the Presbyterian Hospital group was zero.

Hypersplenism.—As a sequel to the two preceding sections, it seems timely to present a recent contribution to the field of hematology. Within the past few years, Doan and his co-workers, and Damashek at still another clinic, have advanced a new classification of splenic disease. These investigators have described what they believe to be a clinical entity, which they have designated as "hypersplenism." Hypersplenism, they maintain, is a functional disturbance and not a specific pathological entity. Except for those cases due to a known cause, the splenic histology is unrevealing, showing "nonspecific hyperplasia."

Two divergent theories have been advanced to explain the pathogenesis of this syndrome. The "sequestration" theory of Doan and his associates involves the phagocytosis of one or more of the cellular elements of the blood, by the spleen. Thus phagocytosis of large numbers of:

Erythrocytes	—→ Hemolytic anemia
Leukocytes	—→ Neutropenia
Platelets	—→ Idiopathic purpura
All three of above	—→ Panhematopenia

As an alternative hypothesis, Damashek holds that the spleen normally exerts a hormonal inhibitory action on bone marrow blood formation. If this inhibitory action is exaggerated, depression of one or more of the cellular elements and hypersplenism may occur.

The term "hypersplenism" is thus disturbingly all-inclusive. The so-called primary forms include splenic neutropenia with or without thrombocytopenia; splenic pancytopenia with nonhemolytic anemia and, lastly, splenic pancytopenia with hemolytic anemia.

Hypersplenism and these cytopenias may be associated with a variety of known causes, such as Gaucher's disease, cirrhosis of the liver, Hodgkin's disease, lymphomas, syphilis, kala-azar, tuberculosis of the spleen,

TABLE 2

INDICATIONS FOR SPLENECTOMY

Splenectomy Indicated	Splenectomy May Be Indicated
Adjunct to other surgery	Hypersplenism
Anomalies	Splenic neutropenia
Rupture	Acquired hemolytic icterus (infectious, toxic lymphoblastoma)
Congenital hemolytic icterus	Secondary purpura haemorrhagica
Idiopathic purpura haemorrhagica	A. Infectious
Congestive splenomegaly (portal hypertension)	1. Pyogenic
	2. Miliary tuberculosis
	B. Toxic
	1. Drugs
	2. Chemicals
	Lymphoblastoma
	A. Giant lymph follicle hyperplasia
	B. Lymphosarcoma
	Gaucher's disease
	Boeck's sarcoid
	Tuberculosis of spleen
	Schistosomiasis
	Splenomegaly of unknown etiology

and malaria. Because of this confusing array of terms, the decision as to which cases are suitable for splenectomy might at first glance seem difficult.

With the possible exception of the group of primary splenic neutropenia, we still adhere to the classification and operative indications given under the other paragraph headings in this paper, and as grouped in the accompanying Table 2.

Congestive Splenomegaly—Portal Hypertension.—The terms "Banti's disease" and "splenic anemia" are finally being superseded by the newer and more descriptive captions of "congestive splenomegaly" and "portal hypertension."

The modern concept of the pathogenesis of this syndrome has been

receiving increasing support from many students of this subject. Based on a considerable array of evidence, it is our opinion that the syndrome is the result of portal bed block with a concomitant state of portal hypertension. The portal bed obstruction may be either (1) intrahepatic or (2) extrahepatic. The hepatic group includes several lesions producing scarring and resultant compression about the portal section of the liver lobule. Only by involvement of a sufficiently large number of portal spaces with blockage of the major volume of portal flow will congestive splenomegaly ensue. It is probably for this reason that only a relatively small percentage of cases of cirrhosis of the liver (not over 20 per cent) develop an associated congestive splenomegaly. Table 3 is an outline of

TABLE 3

SITE AND TYPE OF LESION PRODUCING CONGESTIVE SPLENOMEGALY

I. Intrahepatic block

Cirrhosis of the liver

- a Laennec cirrhosis
- b Schistosomiasis
- c Biliary cirrhosis
- d. Infectious hepatitis

II. Extrahepatic block

A Stenosis of vein (portal or splenic)

- 1 Congenital
 - 2 Acquired (phlebosclerosis)
- B Compression of vein
- 1 Inflammatory cicatrix (following pancreatitis, cholangitis, etc)
 - 2. Pancreatic cyst
 - 3 Tumors
 - 4. Aneurysm of splenic artery

C Thrombosis of vein (portal or splenic)

- 1. Inflammatory
- 2. Traumatic

our experience of the site and type of lesions capable of producing the syndrome under discussion.

The basic clinical and hematological findings are fairly consistent in all cases, with additional overlays dependent on whether or not there is a primary *cirrhosis of the liver*. *Asthenia, pallor, splenomegaly, anemia, leukopenia* and *thrombocytopenia* will be encountered in the cases due both to intrahepatic or extrahepatic block. The dread symptom of *hematemesis* occurs in both. *Hepatomegaly, icterus, ascites* and a macrocytic type of anemia may be added to the foregoing if cirrhosis of the liver is present.

During severe hemorrhage from *esophageal varices* or lower in the gastrointestinal tract the clinical picture will be further altered. Severe grades of anemia in this syndrome are usually only present after in-

testinal hemorrhage. In the posthemorrhagic state, there is also a marked diminution in the size of the spleen. The splenomegaly will again rapidly become apparent after restoring blood volume to normal.

The preoperative studies in these cases, as emphasized earlier, should include a careful evaluation of liver and renal function. It is of paramount importance to determine whether or not cirrhosis is present. The existence of cirrhosis alters our preoperative management and, on a comparable basis with those cases without it, greatly alters our estimate of operative mortality and late results.

As mentioned in earlier communications, the ultimate prognosis and selection of the type of surgical therapy in any given case of portal hypertension will depend on these points: (1) the nature of the obstructive factor, (2) its location, (3) the degree of portal hypertension, and (4) the efficiency of collateral circulation.

Banti early recommended *splenectomy* in what he characterized as the "first stage" of the disease. Thus splenectomy has essentially remained the basic surgical therapy until recently. Although some patients with congestive splenomegaly and associated gastrointestinal bleeding had excellent results, with cessation of bleeding following splenectomy alone (usually those with the block close to spleen), many others (those with intrahepatic block or block close to porta of liver), continued to have recurring hematemesis and/or melena. The majority of this latter group would eventually succumb to an exsanguinating hemorrhage.

Thus it was obvious that splenectomy alone did not prevent recurrence of hemorrhage. Since the failure and ultimate death in the noncirrhotic group is almost always due to hemorrhage, numerous techniques have been evolved in an attempt to control this ominous complication. In the group with the intrahepatic block (i.e., cirrhosis), we have the added problem of liver decompensation and all its attendant possibilities. Direct attempts to control esophageal bleeding include the following procedures: (1) injection of sclerosing solutions into the varices via esophagoscope; (2) ligation of veins about cardia of stomach; (3) esophagogastrrectomy; (4) packing of superior mediastinum; and (5) portacaval shunts. The last three mentioned procedures are all of recent origin, all admittedly "on trial" and all with their respective proponents. Garlock's operation involves packing of the periesophageal tissues in the superior mediastinum. Phemister has reported a few cases in which he has resected lower esophagus and proximal stomach in an attempt to control bleeding.

Combined splenectomy and portacaval shunt has evolved in Whipple's Spleen Clinic and was the sequel of experimental, pathological and clinical studies pursued over a period of years. This group believes that portal hypertension is an essential factor in all these cases of bleeding. In addition, this author does not believe that all bleeding occurs from

esophageal varices. Inasmuch as portal bed block frequently involves blockage of the entire return flow of the superior mesenteric and inferior mesenteric veins in addition to the gastric component, it is not unreasonable to believe that bleeding may occur at any level along the intestinal tract. Pathologists are frequently at a loss to demonstrate a specific bleeding point in an esophageal varix following lethal gastrointestinal hemorrhage. The clinical feature of melena is not infrequently the only manifestation of bleeding. Might this not represent lower intestinal bleeding?

The rationale of a large venous shunt from the portal system to the caval system is thus apparent. On the basis of our present knowledge, it is felt that the surgical procedure of choice is the combined (one-stage) splenectomy and portacaval shunt. Both Linton and the author feel that the surgeon operating on this type of case should be prepared to carry out not only splenectomy but the formidable vascular anastomosis. The technics now in use in several clinics have been described. The use of vitallium tubes seems to be on the wane and direct suture anastomosis of splenic vein or portal vein to some large branch of the caval system is now the technic of choice. Adequate surgical exposure is only one essential to carry out effectively the *meticulous technic involved in vascular surgery*. Whereas our earlier cases were all done by the abdominal route, we now favor the combined thoraco-abdominal approach. In this a transverse upper abdominal incision is continued laterally over the chest wall. The thoracic component is carried through either the tenth or eighth interspace to the midaxillary line. The cases of congestive splenomegaly with cirrhosis of the liver should be selected with great care before surgery is contemplated. A relative state of hepatic compensation must be present and anemia and hypoproteinemia corrected by transfusion. In addition, prior to operation, these patients are placed on a high protein, high carbohydrate diet, with concentrated vitamin supplements. This is instituted and carried out for weeks to months prior to operation.

The two types of shunts used are (1) the splenorenal, i e., end of splenic vein to side of renal vein, with retention of the kidney; and (2) the portal-caval, i e., end of portal vein to side of inferior vena cava or side of portal vein to side of portal vein.

Another type of case in which portacaval shunt is under trial is the postsplenectomy bleeder. This type of case poses serious technical difficulties. The splenic stump is usually a firm, organized thrombus as the result of previous splenectomy and, therefore, unusable. The operator must, therefore, carefully explore the main tributaries of the portal bed

for a large vein to form the proximal limb of the shunt. The possible couplings described to date by various surgeons include:

1. Superior mesenteric vein to inferior vena cava—end to side.
2. Inferior mesenteric vein to left renal vein—end to side.
3. Inferior mesenteric vein to inferior vena cava—end to side.
4. Splenic vein to inferior vena cava—end to side.
5. Double shunt at bifurcation of left renal vein after nephrectomy.
 - a. Splenic vein to one branch.
 - b. Inferior mesenteric vein to other branch (both as end-to-end sutures).
6. Portal vein to inferior vena cava.

SUMMARY

1. Clinical and laboratory aids in the diagnosis of the "surgical splenopathies" are outlined. The value of a new blood test to differentiate the congenital from the acquired type of hemolytic icterus is stressed.

2. The evolution of generic terms in splenic disease to more definitive terms is discussed.

3. The specific indications for surgery of the spleen are outlined, together with a listing of those conditions in which splenectomy is occasionally of value.⁴

4. New surgical procedures have been developed as an adjunct to splenectomy in an attempt to solve the serious problem of gastrointestinal bleeding in congestive splenomegaly.

5. Combined (one-stage) splenectomy and portacaval shunt is advocated for the treatment of congestive splenomegaly (portal hypertension).

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THE TREATMENT OF HEMORRHOIDS

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IN sampling 200 reports of operations for hemorrhoids on various services there were sixteen different methods employed. Several years ago a review of the proctologic literature was stopped after descriptions of over 100 different procedures in hemorrhoidal surgery were read.

When one proposes to write comprehensively on the treatment of hemorrhoids, he is readily aware that the task requires a manuscript of considerable size. This paper will describe only the type of operation the author employs and a new sclerosing solution that we are using in the injection treatment of hemorrhoids on the Third (New York University) Surgical Division of Bellevue Hospital.

OPERATIVE TREATMENT

The operative treatment of hemorrhoids is based upon one of two principles: bringing about atrophy of the hemorrhoidal tumors by shutting off their blood supply, and radical surgical removal. The latter procedure is the better.

The objective in treatment is to maintain or restore the normal anatomy of the anus and rectum as far as possible. This objective is achieved by an operation which,

1. Removes all the vascular tumors.
2. Prevents complications such as bleeding, infection, urinary retention, stricture, loss of sphincter control.
3. Minimizes or obviates postoperative pain.

The following procedure has been adopted as meeting the requirements of the operation. It is a simple excision and ligature operation and was first demonstrated by Jerome M. Lynch. This operation makes use of a simple technic, causes minimal postoperative pain, complications and sequelae.

No hemorrhoidectomies or injection of hemorrhoids are done until a complete rectosigmoidal examination is made.

Preoperative Management.—Patients should be as carefully prepared for hemorrhoidal operations as for any other delicate operation. Forty-eight hours before, either castor oil, milk of magnesia or compound licorice powder is given. On the evening before operation a water irriga-

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small strip of petrolatum gauze is inserted into the rectum and a small padding of dry gauze is applied to the external wound and held in place by a T binder.

The end result of a successful hemorrhoidectomy reveals an anus and rectum that is fairly smooth, intersected by three or four radiating linear scars. There is no edema or puffiness of the wound.

Postoperative Treatment.—Postoperative pain or discomfort is alleviated by 0.1 gm. ($1\frac{1}{2}$ grains) of nembutal or 10 mg. ($\frac{1}{8}$ grain) of morphine sulfate. The gauze strip is removed within twenty-four hours and the patient takes sitz baths twice daily. On the second day a cathartic such as milk of magnesia or compound licorice powder is taken. Mineral oil is given daily for ten days after operation. An oil instillation into the rectum is made with a small catheter before the patient has a bowel movement. The patient's stay in the hospital is three or four days. No digital examination is made until two or three weeks after operation.

Thrombotic External Hemorrhoids.—These are one type of hemorrhoids that do not require hospitalization. Their surgical removal is ordinarily an office or clinic procedure. They are small oval or round tumors that usually come on suddenly, and are situated just beneath the skin or the mucocutaneous area. They produce considerable discomfort or pain and their immediate removal is advisable. They are not true hemorrhoids, but thrombi in the small perianal venules. The majority of these thrombi are outside the sphincter muscle.

Thrombotic hemorrhoids are best removed in the following fashion. A few cubic centimeters of 1 per cent novocain solution are injected into the surrounding area. The small tumor is then grasped with an Allis or Pennington clamp and skin and tumor mass are excised with scissors. If the clot is adherent a small curette will free the fibrous attachment. No suturing is necessary. Oozing can be controlled by pressure. A small gauze wick with a small amount of any anesthetic ointment is inserted in the anal verge and a small dressing applied. The gauze wick either comes out at bowel movement or is removed the following day. The wound is usually healed in three to five days.

Prolapsing, thrombosed and ulcerated hemorrhoids which have become strangulated and have considerable perianal edema are best treated palliatively by wet dressings. Operation is deferred for several days until the infection and edema have subsided.

INJECTION TREATMENT OF INTERNAL HEMORRHOIDS

No treatise on the treatment of internal hemorrhoids would be complete without a discussion of sclerosing therapy. This form of treatment was held in disrepute for a long time as it was practiced by quacks and incompetents. However, at this date, it is widely selected cases, and

the hands of competent and experienced proctologists, the injection treatment has proved successful.

Sclerosing therapy is not to be thought of as a substitute for surgery, nor must it be used indiscriminately. According to Gabriel,⁴ the objects of treatment are (1) to stop bleeding by obliteration of vascular, capillary and venous spaces, (2) to produce a submucous sclerosis which will draw up and fix loose mucous membrane.

Selection of Cases.—Only internal hemorrhoids that are small and uncomplicated may be treated by injection. This method should not be used for the external type or in any case complicated by fissure, fistula, papillitis, cryptitis or in which gangrene or ulceration has occurred.

Advantages.—There are certain advantages that can be claimed for the injection treatment of hemorrhoids.

1. It is a relatively simple technic.
2. It does not require an anesthetic.
3. There is no loss of time from work, or hospitalization.
4. Treatment is painless and there is no danger of hemorrhage.
5. Age, infirmities, cardiovascular or renal diseases, tuberculosis, diabetes or any condition contraindicating an operation are no bar to sclerosing therapy.

Sclerosing Solutions.—Many solutions have been used in the injection of hemorrhoids. Terrell⁵ first introduced 5 per cent solution of quinine and urea hydrochloride. Phenol in almond oil is used at St. Mark's Clinic. Others have used phenol in various strengths, sodium morrhuate, sylnasol, and still other solutions.

For the past four years at our clinic we have employed a new sclerosing solution, which is a branched chain sodium alkyl sulfate (sodium sotradecol). The original experimental work on this solution was done by Reiner. His conclusions were that this solution produced thrombi more readily with less tissue reaction and systemic toxicity than any of the other sclerosing agents, such as phenol, quinine urea, or any of the soap type solutions.

Technic.—Injections can be made with the patient in the left lateral position or in the inverted position. Digital examination is first made with the lubricated finger. Either a Martin-Davis or a Bensaude anoscope is inserted to its full length. One gets an excellent exposure and the hemorrhoids come into clear view. The most prominent hemorrhoid is injected first.

We use either a 2 or 3 cc. syringe with a 3 or 4 inch fine needle. For the first injection 0.5 cc. of the solution is used. The needle is inserted into the superior portion of the hemorrhoidal mass for a distance of about $\frac{1}{2}$ inch and the solution injected slowly. After injection, the needle is not withdrawn until a minute has elapsed.

One of the great errors of the inexperienced is blind injection without good exposure.

Injections are made at intervals of five to seven days. The amount of injected solution is increased to 1.5 or 2 cc. The number of injections is dependent on the size and number of hemorrhoids. At our clinic the minimum number of injections has been four and the maximum has been twelve.

No antiseptic is used before or after injection. If pain is encountered at the time of injection, the fault is with the operator, as he is probably injecting too close to the anorectal line.

No specific after-treatment is necessary, except that patient should avoid physical exercise on the day of, and the day after the injection.

There have been no complications in the cases injected with sotradecol.

SUMMARY

1. A simple technic of hemorrhoidectomy is described. The delicate handling of tissues and the economical use of sutures as factors in lessening postoperative discomfort and pain are stressed.

2. The technic of elliptical excision for external thrombotic hemorrhoids is described.

3. A new sclerosing solution, sotradecol, is discussed in the treatment of internal hemorrhoids. In the writer's experience this solution has been superior to other solutions previously employed.

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THE DIAGNOSIS AND MANAGEMENT OF ABDOMINAL INJURY

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INSTRUCTION of medical students, interns and residents in metropolitan teaching hospitals has indicated the common occurrence of several sources of error in the diagnosis and management of abdominal injury. These are:

1. The high incidence of abdominal injury in conjunction with other more obvious forms of trauma elsewhere about the body. In these instances it is the tendency of the examiner to become preoccupied with the more obvious injury and neglect the possibility of the less apparent abdominal trauma.
2. The frequency of certain extra-abdominal traumatic conditions which produce physical signs simulating those occurring in actual abdominal injury, such as trauma to the spine and thorax. In traumatic occurrences of this nature, there is likelihood that the examiner may assume, from the physical signs present, that abdominal injury exists when none is present.
3. The fact that the true nature and full extent of severe traumatic damage to the contained intraperitoneal viscera may be more or less concealed by the abdominal parietes which may show no indication of external violence whatever. Thus, the examiner may readily presuppose, because of the absence of such marks of violence in the abdominal region, externally, that no injury exists.
4. The presence in many instances of varying degrees of impaired consciousness on the part of the injured subject in association with the abdominal injury so that voluntary cooperation on the part of the patient is excluded, resulting in the loss of many valuable diagnostic criteria. When this complicating feature occurs, estimation of the abdominal injury may be extremely difficult even for the most experienced.
5. A tendency on the part of the examiner, particularly the novice, to delay definitive surgical treatment in instances in which the presence of visceral injury cannot be definitely established because of ambiguous signs and symptoms. This attitude largely arises from

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the hope or expectation that exploratory laparotomy may be avoided. In this connection, it must be recalled that in many cases of severe abdominal trauma the local and general signs may be greatly delayed, or indeed never develop in their so-called classical form until extremely late in the posttraumatic period. It is therefore rational to remind the examiner that conservatism, while commendable, if persistently exercised in all instances may result in grave and even fatal misjudgment by delaying operation.

It is the purpose of this writing to emphasize certain broad features concerned with abdominal injury. These are presented in the belief that if such are kept consistently in mind, many errors from the above and other sources may be consistently avoided.

GENERAL CONSIDERATIONS IN INJURY TO THE ABDOMEN

For purpose of discussion, abdominal injury or abdominal trauma, as they are to be employed here, are general terms denoting lesions of the abdominal wall, contained viscera, or both, produced through the action of applied physical force or its agents.

Viscera of the abdominal cavity may be roughly separated into three categories: (1) solid organs such as the liver, spleen and kidneys; (2) hollow organs such as the stomach, intestines, bladder and gallbladder; (3) supporting structures such as the mesenteries of the large and small bowel, the peritoneal reflections, blood vessels and nerves.

The principal danger in injury to the solid organs and the supporting structures is from hemorrhage and in injury to the hollow viscera from infection or inflammation in the form of peritonitis produced by discharge of their content into the free abdominal cavity. In injury to any of the viscera, regardless of whether the damage is such as to produce hemorrhage, or the intraperitoneal discharge of visceral content, shock may occur from the traumatic disturbance of the visceral organs or the visceral afferent fibers supplying the injured parts. There is some correlation between the physical laws of force and the character of the intra-abdominal injury: *Force applied at one point of the abdomen, if of sufficient degree, may be transmitted in a measure to other abdominal parts which may thus be indirectly affected, and in this regard, the content of the hollow viscera at the time of injury is of considerable importance. When the hollow viscera are empty, they are much less liable to injury than when they are full, and in the event of perforation or rupture, the discharge of their inflammatory content is considerably less; conversely, the larger the content of any hollow viscus at the time force is applied to it, the greater is its likelihood of injury. In this regard, it is important to bear in mind that when the hollow viscera are filled*

with fluid, air or particulate matter, and force is applied, such force is transmitted in varying degrees to all parts of the contained viscus, and rupture is likely to occur at its weakest point. This accounts for bursting lacerations occasionally observed in both the small and large bowel which are removed from the site of contact of the force or agent of injury (for example, rupture of the cecum from a blow sustained in the region of the transverse colon).

The occurrence of visceral injury remote from the site of application of the traumatic force is likewise accounted for by two factors in addition to the relative content of the viscera at the time of injury. The first of these is the disposition of peritoneal bands and attachments which limit the motility of the viscera to which they are affixed. This factor is especially likely to influence the site of perforation or laceration in trauma sustained by the application of force to the abdomen which produces a sudden and violent shift of position of its visceral content. In such instances, the motile parts of the viscera (for example, the large and small bowel) move readily in the direction of the force, but their attached parts remain relatively stationary resulting in undue stress with possible separation or tearing of the visceral wall at the site of the peritoneal attachment: for example, rupture of the small bowel at the ligament of Treitz, and traumatic lesions of the colon, along the lines of attachment at the hepatic and splenic flexures, resulting from blunt force applied to the abdomen.

The second additional factor is the possible presence of pre-existing visceral disease. In such instances when the viscera have been previously altered by pathological processes prior to injury, applied force of otherwise innocuous degree may produce extensive lesions. Such are liable to occur in aged, chronically ill or otherwise debilitated individuals. Thus the possibility of visceral injury remote from the site of application of the force to the abdomen must always be considered, for it may explain the appearance of abdominal physical signs and symptoms in unexpected localities and further emphasizes the necessity for complete exploration of all the viscera once laparotomy has been undertaken.

The character of the content of various hollow viscera is worthy of consideration since there is significant variation in its effect when discharged into the free peritoneal cavity. The content of all hollow viscera is inflammatory by reason of the presence of irritating chemical compounds and pathological organisms. Generally speaking, the pathogenic bacterial content in the gastrointestinal tract increases from above downward, while its irritant-containing chemical secretions decrease. Gastric and small intestinal content, while invariably contaminated with pathogenic organisms capable of producing severe peritonitis,

cause their immediate inflammatory effect by reason of their irritating chemical-containing secretions. The fecal content of the colon, on the other hand, which is most heavily contaminated with pathogenic organisms, has little secretion so that the inflammatory reaction produced is largely of bacterial origin. Bile and urine may or may not be relatively sterile, but their chemical constituents produce a characteristically severe form of peritonitis after a variable latent period, the indicative signs of which may be greatly delayed. Blood itself is sterile and possesses chemical compounds less irritating to the peritoneum so that in the event of the presence of blood alone in the peritoneal cavity, only moderate degrees of peritoneal reaction are produced even when the quantity is considerable.

From the foregoing statements, the generalizations may be made that when the contents of the stomach and small intestine are discharged into the free peritoneal cavity, the inflammatory reaction tends to be immediate and severe, and the signs indicative of peritoneal irritation marked, while with the intraperitoneal leakage of large bowel content, bile and urine, the eventual inflammation may be extensive and severe but will take longer to develop, and the signs at onset are much less marked. Whatever the nature of the discharged content, it, together with the peritoneal exudate which it excites, tends to follow the natural routes of drainage along the pericolic gutters and the pool in the pelvis, and if of sufficient quantity, can be detected there by appropriate examination.

When a quantity of the visceral content is suddenly and rapidly discharged, the signs of peritoneal irritation are rapidly progressive in development, whereas slow discharge or leaks through small visceral lesions may considerably delay their appearance. Even when devoid of other content, the stomach, small bowel and colon contain variable amounts of air. These are the only air-containing viscera and, when they are ruptured or perforated, air is released into the peritoneal cavity. While it is undoubtedly true that free air alone, when so liberated into the peritoneum in sufficient volume, may produce a degree of peritoneal irritation, the significance of its presence is principally diagnostic in value, for if free air in the peritoneal cavity can be satisfactorily demonstrated, it is an undeniable evidence of rupture or perforation of the air-containing viscera. Some confusion is possible, however, in instances of abdominal trauma when a large penetrating wound has allowed the free ingress of external air into the peritoneal cavity. In this event the peritoneally contained air may be either visceral or external in origin, or both.

Practically any visceral organ sustaining injury sufficiently severe is capable of producing grave or even fatal blood loss. Certain organs are

notorious in this respect. These are the spleen, liver and kidneys which, because of their vascularity and structure, are particularly liable, when injured, to prolonged, copious and intermittent bleeding. Injury to these viscera—the spleen and liver most notably—produce a treacherous type of hemorrhage which, even though spontaneously arrested for long periods, is very apt to recur. Rapid exsanguination and death from trauma to these organs has been noted as late as ten days after the original injury. This marked propensity toward recurrent hemorrhage is explained by the fact that the contained vessels of these organs are thin-walled, and the consistencies of the organs themselves are of an unresilient and friable character so that effective retraction of the vessels and subsequent sealing by clot does not effectively occur. Moreover, when hemorrhage from these parts is spontaneously arrested, the circulation through them is so abundant and fluctuant with respect to pressure that the hemostatic clot is particularly liable to extrude from the injured vessels with any significant change in blood pressure, and hemorrhage is liable to recur.

Whenever severe injury is caused to intra-abdominal viscera, with or without concomitant discharge of blood or visceral content into the free peritoneal cavity, there is practically always reflex inhibition of intestinal peristalsis. This is prone to occur at or very soon after the time of injury, and to continue for a variable period, according to the extent of the trauma. Usually when perforation or rupture of a hollow viscus has been produced with consequent discharge of its inflammatory content into the peritoneum, the peristalsis diminishes with the increasing inflammatory reaction. Even in the event that no intraperitoneal discharge of visceral content or hemorrhage has occurred, contusion of the viscera may produce the same effect. In any instance, therefore, of potential intra-abdominal injury, the activity of the peristalsis should be observed, for its absence taken in conjunction with other findings is a significant sign of visceral injury.

Unfortunately, other traumatic conditions are capable of simulating abdominal injury when no such injury exists, and these must be carefully eliminated before it can be stated with certainty that there is definitely an intra-abdominal lesion present. These are thoracic and spinal traumatic conditions, both of which may closely imitate certain types of intra-abdominal trauma. This largely arises from the fact that the abdominal parietes receive their innervation from the lower six thoracic nerves, which proceed from the spine subcostally to their respective segments of the abdominal wall, so that injury to the spine or thorax in the region of the course of these nerves produces referred sensory pain, tenderness, hyperesthesia and reflex motor spasm which are localized to the abdominal wall as well as present at the site

of injury. It is obvious that such injuries may also exist together with intra-abdominal trauma, in which instance evaluation of the abdominal signs may be difficult indeed. Many or most of the significant signs indicating the presence of severe intra-abdominal trauma arise from stimulation of the cerebrospinal and visceral afferent nerve fibers by trauma to the abdominal wall, to the contained viscera, and to the presence of discharged content in the peritoneal cavity, and it must be determined that the abdominal signs present arise from these latter causes rather than from the extra-abdominal injuries noted above.

BASIC CONSIDERATIONS IN PENETRATING AND NONPENETRATING ABDOMINAL INJURY

For considerations concerned in both diagnosis and management, all abdominal injuries, regardless of their specific nature or particular type of causal agent, are classified into two principal categories:

1. Penetrating abdominal injuries in which the abdominal lesion, of whatever extent, is produced by an agent or force which has actually penetrated into or through the thickness of the abdominal wall, and possibly the viscera beyond by demonstrable wound of entrance; and
2. Nonpenetrating injuries in which the force or agent of injury has not made actual penetration into the abdominal parietes, but which may have damaged the contained intra-abdominal viscera.

The causal agents of the penetrating abdominal injury are generally in the nature of forcible contact with objects of relatively small area of surface contact such as points, edges, and missiles of various caliber and velocity. These produce in the main incised, lacerated or perforated wounds upon the external surface

Nonpenetrating abdominal injuries, on the other hand, occur from forcible contact with agents giving larger areas of surface contact such as broad, smooth or irregular surfaces, and these produce external lesions upon the abdominal surfaces in the nature of contusion and abrasion in most instances, but may cause no evidence of external violence whatever.

The same causal agents which produce severe penetrating and nonpenetrating intra-abdominal injuries may cause only superficial abdominal lesions without damaging the internal viscera, in which instance only conservative management and no operative intervention is indicated. Therefore, the principal decision confronting the examiner of abdominal trauma is whether or not severe injury to the contained abdominal viscera has occurred. This decision is frequently extremely difficult in both penetrating and nonpenetrating types of abdominal trauma. Penetrating abdominal injuries are, as a whole, somewhat less

of a problem in this regard because in a high percentage of such cases the evidence of deep intraperitoneal penetration is immediately apparent. It is thus a matter of convenience to further classify penetrating abdominal injuries into:

1. Penetrating intra-abdominal injuries in which the intraperitoneal penetration and visceral injury are obvious from the nature of the external lesion; and
2. Penetrating intra-abdominal injuries in which the intraperitoneal penetration and visceral injury are not obvious from the nature of the external lesion and must be otherwise determined from local and general signs.

Penetrating intra-abdominal injuries of the obvious type include those in which there is exposure or herniation of the abdominal viscera through the external wound; those in which the wound of entrance and exit indicate a line of traverse through the peritoneal cavity; and those in which the agent of injury has obviously been retained in whole or in part within the peritoneal cavity. Obvious intraperitoneal injuries of this kind present little or no diagnostic problem and the indicated management is much the same in all instances—treatment of any extant shock or hemorrhage, and exploratory laparotomy as soon as the patient's general condition will allow.

It is with the second type of penetrating abdominal injuries, namely, those in which the intraperitoneal penetration is not obvious from the external abdominal lesion and must be determined by other means, that difficulty is principally encountered. Concerning this latter type of penetrating intra-abdominal trauma, certain points are worthy of consideration. Frequently external wounds, seemingly of only a superficial character, are later revealed to have entered deeply and produced extensive intraperitoneal damage. Attempts to demonstrate by probing the depth of penetration of the external wound upon initial examination are dangerous and useless, and the information thereby gained is notoriously inaccurate.

When it is recalled that wounds through the skin and superficial fascia may, because of the movement of the body, be far removed from the tract taken through the deep and underlying structures, the futility of probing the superficial portion of the wound to gain information as to its depth and traverse is apparent, and failure to demonstrate a complete penetration through the abdominal wall by the method of probing in no way precludes intraperitoneal entrance. Moreover, injudicious use of the probe is likely to cause recurrence of hemorrhage already arrested, breakdown of tissue barriers which have sealed off the injured parts, introduction of infectious material into the depth of the wound, and the creation of false tracts in the deep tissue. In the main, therefore, in

the splenic flexure mobilized. The wound was closed about the splenic flexure, which was left as a new colostomy.

The patient was lost to follow-up for one year, but reappeared in January 1948 because of a large ventral hernia that had developed about the colostomy. On February 18, 1948, the incision was again opened, and the colostomy freed. A passage was dissected through the densely matted pelvic tissues and the colostomy pulled through the anus.

Following this procedure the patient was incompletely obstructed for ten days. This corrected itself and she made a satisfactory recovery.

In one instance, previously mentioned, we were unable to bring the proximal colon to the anus because of a short left colon and fixation about the colostomy site. This necessitated a staged rotation of the transverse and descending colon for anastomosis.

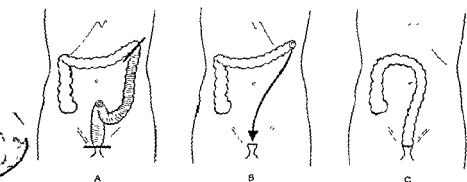


Fig 160 (Case I)—A, First stage. Resection of colostomy and involved segment of bowel. B, C, Second stage. Anastomosis of stoma of splenic flexure to rectal stump.

CASE II (Fig 161)—I G, a Negro woman, aged 43, was admitted to the Fourth Surgical Division of Bellevue Hospital on May 22, 1946, with a tubular rectal stricture and signs of incomplete large bowel obstruction. The Frei test was positive. A defunctioning colostomy was performed on May 22, 1946. Subsequent roentgenograms showed the granuloma to involve the entire rectum and two-thirds of the sigmoid.

On March 13, 1947, the involved rectum and sigmoid were resected by a perineo-abdominal procedure. Because of fixation at the colostomy site the descending colon could not be mobilized and brought to the anus. As the patient's condition was not satisfactory the proximal bowel end was left in the wound as a colostomy stoma. On May 16, 1947, the left half of transverse colon was detached from the colostomy site, and mobilized with the descending colon. The ends of this segment were again implanted in the lower angle of the wound after rotation to the left around its blood supply. On September 17, 1947, the distal stoma was freed abdominally, and anastomosed to the anal canal through a perineal incision. Restoration of continuity was completed on February 24, 1948 by anastomosis of the functioning colostomy stoma in the right half of the

transverse colon to the proximal end of transplanted portion of transverse and descending colon.

Eight months after operation this patient had good control despite the fact that the perineal body had been partially destroyed by the previous perineal infection.

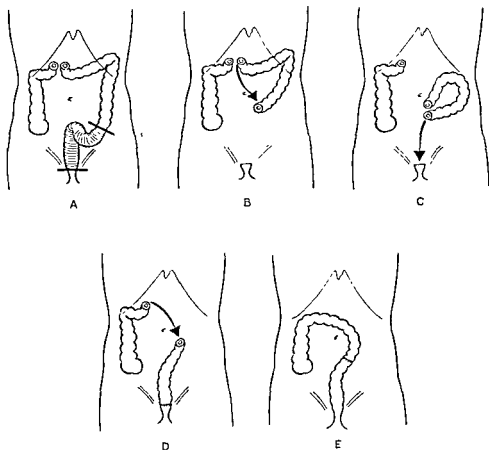


Fig. 161. (Case II).—*A*, Second stage: Resection of involved segment after defunctioning colostomy. *B*, Third stage: Proximal stoma of distal segment brought down to distal stoma. *C*, Fourth stage: Distal stoma anastomosed to rectal stump. *D*, Fifth stage: Remaining colostomy stomas anastomosed. *E*, Anastomoses completed.

Mobilization and rotation of the bowel is successful as long as the transposition is performed without tension. Forceful pulling down of the bowel compromises the blood supply and is followed by slough of the mobilized segment.

CASE III.—S. S., a Negro woman, aged 51, was admitted to the Fourth Surgical Division of Bellevue Hospital on August 19, 1941 with a tubular rectal stricture involving the anal canal, entire rectum and distal portion of sigmoid. There were multiple fistulas between the rectum and vagina. After a defunctioning colostomy on August 28, 1941, the patient was lost to follow-up. When she was seen again in November 1947 the local infection had healed well. On

December 12, 1947 the involved sigmoid and rectum were resected by a combined abdominoperineal procedure. Because of complete fibrosis of the rectum and anal canal, the sigmoid had to be pulled through the sphincters. Improper estimation of the length of the mobilized segment resulted in this being pulled through under tension. This was followed by slough of the entire segment. It will be necessary to mobilize the splenic flexure and transverse colon through the abdomen if she is to be further improved.

PREOPERATIVE PREPARATION AND POSTOPERATIVE TREATMENT

Patients are prepared for colostomy with succinylsulfathiazole for five to seven days. During this period the necessary chemical and hematologic studies are made. Severely depleted individuals may require transfusion before the colostomy is performed. Elaborate preparations are unnecessary for the ensuing stages as these are not attempted until the patients have regained their normal status.

Replacement of blood loss is the most important feature of postoperative care. These extensive resections and mobilizations of the large bowel are attended by severe blood loss because of the large amount of cicatricial tissue present. Massive transfusions during and after operation allow the patient to withstand these procedures well. Routine use of sulfonamides and penicillin postoperatively are unnecessary unless some specific indication exists. Before the colostomy is closed, succinylsulfathiazole is resumed for five to seven days.

RESULTS

During the past six years we have operated upon twenty-one patients for elimination of the disease and restoration of gastrointestinal continuity. There have been seventeen good results, one fair result, two failures and one undetermined result. A patient without evidence of disease and sphincter control is considered a good result. Narrowing of the bowel secondary to the surgical procedure is considered a fair result even though sphincter control may be present.

The patient classified as a fair result had narrowing at the site of anastomosis secondary to separation of the anterior portion of the suture line. This anastomosis had been made between the transverse colon and the rectum just above the pectinate line, after resection of the rectum, sigmoid and descending colon. Despite the surgical stenosis of the rectum this man has a good functional result.

The failures are the patient previously summarized, whose bowel sloughed after being pulled through the sphincters under tension, and a patient who had prompt recurrence of the disease after resection. This recurrence was due to inadequate removal of bowel, as the granulomatous process reappeared at the anastomotic site. This patient has

been reoperated upon successfully and may be now considered a good result, as there has been no evidence of recurrence one year after the secondary resection and closure of the colostomy.

The patient whose result is classified as undetermined was found to have schistosomiasis as well as lymphogranuloma venereum in the operative specimen. Six months after operation she returned to Puerto Rico so that the final outcome is unknown.

There have been no deaths among the twenty-one patients operated upon for elimination of the disease and restoration of intestinal continuity. There has been one death following colostomy, in an acutely ill patient, in whom autopsy showed no cause of death. We believe this fatality was due to leaving the proximal colostomy clamp in place for too long a period. A second death occurred in an elderly woman following revision of a loop colostomy which had become involved by upward extension. This patient developed anuria after resection of the left colon, and died of uremia. This can be attributed to a faulty appraisal of the patient and might have been prevented by staged procedures.

Follow-up has been good considering the unstable stratum of the metropolitan population from which these patients are drawn. There were four patients who have been followed for five years, three for one and a half years, five for one year and eight for six months without evidence of recurrence. One patient in the group followed for one year developed carcinoma of the stomach from which she eventually died. All patients followed have maintained their improved general condition. Two patients have continued to have polyarthritis which had developed before treatment was begun. This complication has remained despite weight gain and great improvement in general condition.

CONCLUSIONS

1. Lymphogranuloma venereum of the rectum can be eradicated and intestinal continuity reestablished with good functional results.
2. Defunctioning colostomy should precede any attempt to eradicate the local process.
3. A more satisfactory result is obtained when anastomosis is performed just above the anal canal rather than pulling the bowel through the sphincters.
4. Variation in the extent and severity of involvement necessitates a flexible plan for management of each case.
5. Where extensive resection of the left colon has been necessary, careful preservation of the marginal artery permits rotation and advancement of the splenic flexure or transverse colon to the pelvis for restoration of continuity.

6. Follow-up of patients postoperatively indicates a high proportion of satisfactory results that justify this procedure.

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TREATMENT OF PERFORATIONS OF THE SOLID ABDOMINAL VISCERA

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PERFORATIONS of the solid abdominal viscera have been seen with increasing frequency in peacetime as a result of the speed-up of modern transportation. Automobile accidents probably constitute the greatest source of injuries which cause perforations of the solid viscera. Perforations of the kidney, liver, spleen and pancreas occur as a result of wounds which are either penetrating or nonpenetrating. In civil practice, nonperforating wounds are the more common, while in military practice, perforating wounds are frequently seen and additional knowledge of the treatment of such wounds was obtained during World War II.

KIDNEY

The kidney is the organ which suffers most frequently as a result of wounds which cause perforation of its structure. In 62,000 surgical cases at the Johns Hopkins Hospital,¹ there were twenty-five injuries of the kidney, eight ruptures of the spleen and six of the liver. The diagnosis of renal injury is made on the basis of the history of trauma and the finding of clinical evidences of shock together with microscopic or gross hematuria. The kidney lies embedded in perirenal fat, but despite this, it is frequently injured by sharp compression between the costal border and the pelvis in jackknife accidents or by a sudden sharp blow over the loin space. An example of the latter follows.

A Temple University student on his way to school slipped while climbing the subway steps and fell, striking his left side on the sharp edge of one of the steps. He was momentarily stunned but continued up the steps by his own volition and attended his first class. Between classes he felt the urge to urinate and on doing so noted that the urine was grossly bloody. At the same time he began to complain of faintness. He returned to his home and called his family physician who promptly ordered him to report to the hospital. On admission the patient was pale, pulse rate was 110 and blood pressure was 90/50 mm. of mercury. The patient was immediately typed for blood transfusion. Intravenous plasma was given and prompt exploration of the left kidney region was performed under general anesthesia. The left kidney was found to be completely shattered by a

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stellate wound in its midportion extending into the region of the pelvis Nephrectomy was performed with recovery.

Contusions of the kidney may at times be confused with penetrating wounds or rupture. Shock is often a presenting symptom and hematuria is either microscopic or gross. Such cases must be followed carefully by frequent examinations of the urine, repeated red blood counts, examination of the area involved for evidence of extravasation of urine or blood and intravenous urograms

The treatment of penetrating wounds of the kidney is governed by the portion of the kidney involved. If the injury affects the pelvis of the kidney and interferes with its blood supply, nephrectomy is mandatory. If the perforation is clean-cut and of a through-and-through nature, as might be obtained by a bullet or stab wound, therapy may be employed to conserve renal tissue. In cases in which hemorrhage is the secondary rather than the primary consideration, nephrostomy should be done. Occasionally, injury is confined to the upper or lower poles. In such cases heminephrectomy should be performed and bleeding from the cut surface of the kidney controlled by means of mattress sutures tied over a fat graft or a hemostatic such as gelfoam.

The differential diagnosis between injury to the left kidney and to the spleen may be difficult especially after automobile accidents where the contused area is not sharply localized. The following case illustrates this point.

A 33 year old woman was a passenger in an automobile which was struck by another car. She was immediately brought to the hospital. On admission she was conscious but had extreme pain which was noted on the left side of the abdomen. The pulse rate was 120 beats per minute and the blood pressure was 120/110 mm. of mercury. There was blood in the urine. However, a tender mass was felt in the left upper quadrant just below the costal border. It was felt that the primary injury was a rupture of the spleen with secondary involvement of the kidney, despite the absence of positive x-ray evidence of splenic rupture. Abdominal incision revealed the spleen to be intact, but exploration of the left kidney showed it to be completely bisected and nephrectomy was done which was followed by uneventful recovery.

LIVER

According to Martin,² manifestations of injury to the liver depend on indirect and direct forms of trauma and the effects are dependent on the degree of initial trauma and subsequent complications. If the injury is extensive and crushing in type, the hepatorenal syndrome may develop. The usual clinical manifestations are those associated with shock.

hemorrhage, biliary peritonitis and infection. When the diagnosis is made, surgical intervention is indicated after treatment of shock and hemorrhage has been instituted. Penetrating wounds of the liver may be treated by suture, packing, insertion of muscle graft or omental graft, or any of these in combination with one of the newer hemostatic agents such as gelfoam, fibrin foam or oxycel. Suture alone is seldom satisfactory for a tissue as friable as the liver, especially in the presence of injury. Packing with gauze will control the immediate hemorrhage in most cases but should never be used because of the danger of secondary hemorrhage when the gauze is removed. The following case illustrates this point.

A soldier, 21 years of age, was thrown from a rapidly moving automobile when it struck a bridge abutment. Shortly after the injury, he was brought to the hospital. Symptoms of shock were pronounced and there was a contusion over the right lower costal area with marked tenderness and rigidity of the muscles in the right flank. Following intravenous therapy with blood and plasma, operation was carried out and a large rent was found on the superior surface of the right lobe of the liver. This extended 4 inches into the substance of the liver and bleeding was profuse. The hemorrhage was controlled by means of gauze packing and the postoperative course was very satisfactory. Removal of the gauze was gradually begun eight days after the injury. On the twelfth postoperative day, the last bit of gauze was removed. This was followed within two hours by a sudden massive secondary hemorrhage and the patient died before reoperation could be performed.

The use of a free or pedicled muscle graft or a free graft of omental fat is much more satisfactory because such a pack does not require subsequent removal. These grafts may be used alone or in conjunction with a hemostatic. The following case demonstrates this method of treatment.

A girl of 10 was riding her bicycle and fell off, striking herself on the right side with the point of the handle bar. She was brought to the hospital complaining of pain in the right side and tenderness throughout the right abdomen. There was a small area of redness caused by the contusion at the lower border of the costal cage. It was the impression that the child had a penetrating wound of the liver. Operation was performed under ether anesthesia. On opening the peritoneal cavity, a great deal of blood was encountered. Exploration revealed a deep lacerated puncture wound of the right lower lobe of the liver which was bleeding freely. A piece of the great omentum was separated from its attachment and placed in the wound over a piece of gelfoam. The tear in the liver was loosely sutured with interrupted chromic catgut sutures over the omental graft. This completely controlled the hemorrhage and the abdomen was closed without drainage. The patient was discharged from the hospital ten days later.

SPLEEN

Penetrating injuries of the spleen are commonly seen following trauma of automobile accidents, sledding, and football injuries. While the spleen is an organ which is not essential to life and may be removed without danger to the future welfare of the patient, Mazel³ feels that it should be preserved whenever possible. If the vessels of the splenic pedicle are injured, splenectomy is imperative and must be performed without delay. The diagnosis of hemorrhage from a traumatic per-



Fig. 162—X-ray findings characteristic of ruptured spleen. Note obliteration of the splenic shadow, dilatation of the stomach with serrations along the greater curvature and increased density along the greater curvature.

foration of the spleen may be difficult and at times may be arrived at only by exclusion of the kidney and other viscera as cause for the signs of hemorrhage and shock. Solis-Cohen and Levine⁴ have demonstrated characteristic x-ray signs (Fig. 162) in cases of splenic injury, namely, obliteration of the splenic shadow, dilatation of the stomach with serrations along the greater curvature, and increased density along the greater curvature. When these findings are present in addition to the history of trauma, when tenderness and muscle spasm are present in

the left upper quadrant of the abdomen, exploratory operation is indicated.

Blood transfusions should be instituted as soon as possible to replace blood lost. At operation, considerable blood may be found in the peritoneal cavity and this may be aspirated and returned to the patient immediately as an autotransfusion. If the injury does not involve the splenic pedicle and is found to be a simple superficial tear, two or three mattress sutures approximating the wound edges should insure perfect hemostasis. However, if the spleen is fragmented, splenectomy is imperative. One cubic centimeter of epinephrine hydrochloride is injected hypodermically to make the spleen contract and empty itself of blood which is thrown into the circulation as a supportive measure just before clamping the splenic vessel. Finally, it should be remembered that the signs of splenic rupture may be delayed for months after the injury has occurred and long after the trauma has been forgotten. The first symptoms may be those of concealed hemorrhage, and while the diagnosis in such cases is more difficult, the treatment is the same as outlined above.

PANCREAS

The most interesting of all the perforating injuries which affect the solid abdominal viscera are those which involve the pancreas. The pancreas is the least commonly injured of all the solid abdominal viscera because it is well protected by overlying structures. Trauma is particularly likely to occur in thin subjects when the pancreas is forcibly compressed between a protruding object and the vertebral column. If the injury is severe, the symptoms resemble those caused by an attack of acute pancreatitis with generalized abdominal pain and boardlike rigidity. These symptoms are due to the escape of pancreatic ferments and require incision and drainage of the area involved. This may result in the formation of a pancreatic fistula which usually heals within two weeks. Such an injury may also be followed by the formation of a cyst of the pancreas which will require subsequent treatment.⁵ Not infrequently, cysts of the pancreas result from injuries sustained months before. The following case is an example of this type of injury.

A soldier, 19 years of age, was going through an obstacle course. While attempting to climb a picket fence, he fell heavily across the top of the fence. Following the injury, he was hospitalized for approximately one week during which time pain and deep tenderness in the abdomen gradually disappeared and he was returned to duty. Three months later he was admitted to another Army hospital because of a swelling in the epigastric region. This was fluctuant and was producing symptoms of large intestinal obstruction. Operation was advised, and on abdominal exploration, a large cyst arising from the pancreas

was evacuated. The cyst was marsupialized and packed lightly with gauze. After removal of the gauze, drainage persisted for four weeks, but then ceased entirely and there was never any recurrence of the cyst.

Such cysts are rarely excisable because of the inflammatory reaction which they evoke in surrounding tissues. In some instances, drainage persists for many months. In these cases the drainage tract may be anastomosed to the jejunum, producing an internal pancreatic fistula.

SUMMARY AND CONCLUSIONS

Perforating wounds of the solid abdominal viscera are seen with increasing frequency mainly as a result of the speed-up of modern transportation. The kidney is the most commonly injured of the solid abdominal viscera. The treatment of such injuries may be conservative or radical depending on the extent of the injury and the portion of the organ involved.

Next in order of frequency are injuries which affect the liver. Treatment of such injuries to the liver must be based on the fact that this organ is essential to life and its structure is such that special methods are necessary to insure proper surgical treatment of perforations. Newer developments in such methods are discussed.

The spleen is also subject to traumatic perforations. While it is not an organ essential to life, efforts should be made to preserve it whenever possible. The methods for doing so are discussed.

The least commonly injured of all the solid abdominal viscera is the pancreas. In many respects the injuries to the pancreas are the most interesting because of the late complications which may follow such injuries. The treatment of acute injuries of the pancreas and their late complications are reviewed.

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EXAMINATION OF THE LOWER BOWEL

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In the process of the routine physical examination the lower bowel is neglected more frequently than any other accessible region of the body, and there is no logical explanation for this oversight. Accurate statistics have never been collected concerning the satisfactory examination of the lower bowel as a part of the routine physical examination, but questioning of patients who come to the office will show that the procedure has been omitted in a surprising number of cases. It is of interest to note that many physicians and surgeons who treat bowel disease do not actually possess a proctoscope.

IMPORTANCE OF THE RECTAL EXAMINATION

There is irrefutable evidence that a good rectal examination is of utmost importance in every complete physical examination. Malignant disease of the lower bowel furnishes a dramatic example of this point. It is known that approximately 12 per cent of all malignant tumors of the body are found in the anus, rectum and sigmoid.¹ Eighty per cent of all intestinal cancers, excluding those of the stomach, are located in this region, and of these, 90 per cent can be diagnosed by proper rectal examination.

The rectum is usually examined only if symptoms referable to this region are presented, yet it is common knowledge that early cancer in this region is frequently asymptomatic. The symptoms commonly associated with malignant growths of the lower bowel, i.e., changes in bowel habit, rectal bleeding, pain and constitutional changes, are relatively late manifestations.

There is good evidence² that carcinomas of the lower bowel begin as benign polyps, hence the importance of disclosing a precancerous lesion can hardly be overemphasized. For example, among patients with cancer of the lower bowel, brought under observation in all different stages of growth, not more than 650 in a thousand will be found in an operable stage, and of these only 600 will survive the procedure. Around 300 will be alive in five years, and only 150 will remain alive for ten years. This seems an unduly high price for the patient to pay since the 5 per cent of persons carrying these lesions could be found by routine proctoscopic examination, and the destruction of the polyp by a simple office procedure might prevent a radical operation giving the patient only a 15 per cent chance of living ten years.

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TECHNIC OF RECTAL EXAMINATION

It is essential that both the digital and endoscopic examination be included in the routine physical examination, for each discloses factors which are quite different but equally important.

The digital examination should precede the insertion of any instrument through the anal canal. Before introduction of the finger, the buttocks should be retracted and the anal ridge everted. By this simple maneuver the examiner may detect squamous cell carcinoma of the anus, external fistulous openings, pruritic skin changes, condylomas, anal chancre, thrombi, skin tags and anal fissures. When patients suffering from anal fissures or pruritus ani are referred to the proctologist with the diagnosis of hemorrhoids, it is evident that even the observation of the anal area has been neglected.

Digital examination is carried out simply by inserting the lubricated, protected finger through the anus into the rectum. The reluctance to carry out this simple procedure is possibly purely aesthetic. Buie³ approaches this problem in a healthy fashion when he states that he would gladly insert his finger into the rectum of a person professionally with whom he would not care to shake hands socially.

This examination should not be attempted casually but done in a careful and methodical manner. The tone of the rectal sphincter should be noted, and any area of induration in the anal canal or anorectal junction should be explored for fissures or internal fistulous openings. By placing the opposite index finger on the anal ridge, a bidigital palpation of the intervening tissue around the circumference of the anal canal will detect deformities of the coccyx, perianal abscesses, fistulous tracts, sebaceous cysts, dermoids, and other tumor masses. Following this, a careful palpation of the entire rectal wall is made as high as the finger can reach, with bimanual assistance. Normal landmarks such as the prostate and the cervix are identified.

One should not be satisfied with the mere diagnosis of a lesion; a complete inventory should be made and all information obtained that careful palpation makes available. In the presence of a carcinoma,⁴ for instance, the growth may be movable or fixed. It may be so small as to be barely palpable, or it may be large enough to fill the rectal ampulla. The degree of the encirclement of the lumen should be noted, and whether it is tubular or diaphragmatic. Submucous thickening may be present and may indicate extension under the mucosa. Lymphatic spread may be detected by palpation of nodules posteriorly or posterolaterally. All these findings give valuable information regarding operability and prognosis.

Blumer's shelf may be produced by secondary implantation of cancer

cells from the stomach, ovary or bowel, and a "frozen pelvis" may be the result of extension of cervical or uterine carcinoma, infection or endometriosis. General thickening and roughening of the bowel may suggest chronic ulcerative colitis, and strictures and contractures are readily identified. Adenomas and polyps are notoriously elusive. Small ones are frequently missed, but those of larger size may be felt as soft, pedunculated or sessile elevations. Abscesses are identified as tender masses bulging into the lumen from the wall (intramural) or from the pararectal spaces. The prostate and seminal vesicles should be explored for induration and masses. Fecal impactions are easily detected by digital examination.

Additional information may be gained by the simple expedient of having the patient force down in a squatting position, for frequently only by this maneuver is one able to observe prolapsing polypi, rectal mucosa, or internal hemorrhoids. Also in this same vein, when the patient complains of "something prolapsing," the doctor may save himself embarrassment if he gives the patient the benefit of the doubt and instructs him to return when the mass is evident, rather than dismiss him as entirely normal.

THE USE OF THE SIGMOIDOSCOPE

Following the digital exploration the sigmoidoscope should be used routinely. This simple instrument may be employed quite satisfactorily with relatively little training, but unfortunately most doctors finish medical school without adequate instruction in its use. Until medical schools emphasize the importance of this instrument and afford their students the opportunity to utilize it, we can hardly be too critical of the practicing physician who fails to employ it.

Any one of the numerous standard types of sigmoidoscope is adequate. Although the special table for inverting the patient is more comfortable, the examination can be performed satisfactorily with the patient in the knee-chest position.

While the examination by the endoscope is not without danger when conducted by one lacking in experience, hazards may be completely eliminated by following a few simple rules. Digital examination should always precede the introduction of the instrument in order that the examiner may be forewarned of anal stenosis, low stricture or obstructing masses. As soon as the scope is passed beyond the sphincter, the obturator is removed and the instrument is passed from that point under visual guidance. A minimal amount of air is introduced into the bowel, the purpose being to remove redundant folds of mucosa from the line of vision rather than to balloon out the bowel. The instrument

should not be advanced until the lumen can be clearly identified; it should never be forced. If gentle manipulation will not permit passage, then efforts should be discontinued.

Certain methods of preparation and handling make for easier and more pleasant investigation of the lower bowel by the sigmoidoscope. Our routine preparation consists of a tap water enema which is repeated until the returns are clear, this is taken one to two hours before the appointment. X-ray examination of the bowel is always preceded by proctoscopic examination, as we believe that any indication for a barium enema is an indication for thorough lower bowel investigation. For the best cooperation of the patient, avoid having several persons give instructions; also avoid such expressions as "relax" and "breathe through your mouth," for these are not at all reassuring. The only voice heard during the procedure is that of the examiner, and the patient should be forewarned of each sensation to be experienced before it is noted. The patient should be warned that he will feel that he must have an urgent bowel movement when the instrument is introduced, but that the bowel will actually not function. Otherwise, the fear of embarrassment will frequently cause considerable strain, and make further examination difficult or impossible. The manipulation of the scope about the angle of the rectosigmoid usually causes tension on the mesosigmoid, and at that point the patient should be forewarned of abdominal cramps which will soon pass off. This type of "vocal anesthesia" is considered a highly important part of the examination, for by so gaining the confidence of the patient, relaxation is achieved.

The scope should be passed to its full length as rapidly as is consistent with the absolute safety and comfort of the patient. The examination is done as the instrument is being withdrawn, and if too much time is consumed in introducing the scope, the patient may become tense, resulting in straining and poor visualization.

As the instrument is withdrawn, it is rotated in such a manner that the whole circumference of the bowel is observed and careful inspection is made of all areas. In this way small adenomas and polyps are visualized, and neoplasms may be brought into direct view and studied in a detailed manner. Biopsies may be easily and safely taken and the nature and grade of the tumor accurately determined. Diverticulitis may be diagnosed by noting fixation, thickening, loss of elasticity and narrowing of the bowel in the rectosigmoid region, and rarely the diverticula may be seen as small slitlike openings in the bowel wall. Ulcerative colitis can be diagnosed, evaluated and its course followed satisfactorily by means of endoscopic examination. There are those who feel that this is the only accurate means of determining progress in the disease, and that it should be treated only by physicians using this instrument

Irradiation proctitis following radium in the cervix and radiation to the pelvis in general presents a characteristic picture. The ulcers of *Endamoeba histolytica* are usually typical in appearance, and proctoscopic examination often gives the first hint as to the existence of this disease. Tuberculous ulcers are fairly characteristic, and diagnosis may be established by means of a biopsy specimen. Other forms, such as proctocolitis due to the gonococcus, bacillary types and lymphopathia venereum, are diagnosed by the typical pictures presented. Rarely a diagnosis of endometriosis may be established by observing the implants in the bowel lumen.

SUMMARY

The importance of the routine investigation of the rectum and sigmoid as a part of each complete physical examination is stressed.

The technics of the adequate methods of examination are outlined.

An appreciable improvement in the present status of cancer of the lower bowel can be expected only when each individual physician routinely investigates adequately and thoroughly the asymptomatic as well as the symptomatic bowel.

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THE CONDUCT OF ANESTHESIA DURING ABDOMINAL SURGERY

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WHEN one proposes to discuss comprehensively or evaluate critically the application of the numerous anesthetic procedures to abdominal surgery, he is readily aware that the variable factors to be considered are even more numerous than the physiological disturbances of surgical patients and the pharmacological differences of anesthetic drugs. The surgeon and his requirements, the anesthetist and his limitations and the conditions under which operation has to be completed must be considered also. This discussion is limited to a review of some of the most important factors rather than an attempt to set forth a stereotyped anesthetic regimen which may be applicable to groups of patients subjected to abdominal manipulations.

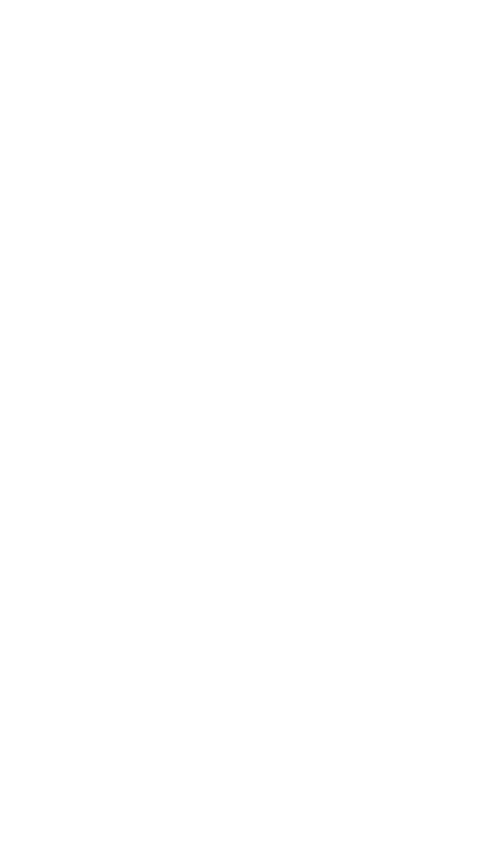
THE FALLACY OF ROUTINE MANAGEMENT

It might be well to initiate such a discussion by pointing out certain fallacies that have invaded anesthetic teaching and practice of this subject. One fallacy is the frequently expressed conviction that anesthetic drugs and technics should be or may be correctly chosen routinely for a given operation. It should be recognized without argument that the primary consideration in the selection must be the patient in precisely the same fashion that a surgeon proposes appendectomy for appendiceal disease rather than the fact that he can perform an appendectomy with greater finesse than a total gastric resection. It is the patient who must be treated. Abdominal operations of many types are performed for the young and aged, the strong and weak, the healthy and chronically ill. They are completed under various circumstances as elected or in an emergency and with innumerable complications and hazards present. All these variable factors mitigate against fitting a patient to an anesthetic regimen simply because a given surgical procedure is to be done. It has been taught, also, that a known pharmacological action of a given agent contraindicates its use for patients with certain specific disease processes. This does not follow regularly since other factors may be much more important. In the selection of an anesthetic procedure, cer-

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condition cannot expect to serve as a consultant in the selection of methods. The surgeon who insists upon dictating the anesthetic procedures is either without confidence in the anesthetist or is displaying his prejudices. Similarly the anesthetist who proposes to provide the anesthesia of his independent choice seeks to glorify his position on the surgical team or is not capable of applying the many advances in anesthesia to his practice. The proper choice of anesthesia should be made by the surgeon and anesthetist and frequently with the aid of other consultants after considering all factors entering into the successful completion of the operation. The agent and technic should be chosen not on a basis of the preference of either but because of known contraindications and indications from the standpoint of the patient's recovery and secondarily the operation.

THE MAJOR IMPORTANCE OF TECHNICAL SKILL

The foregoing remarks may appear to give unnecessary emphasis to the selection of anesthesia. It is well understood that the great majority of surgical procedures are relatively simple exercises upon patients with little or no serious impairment of their physical status. The number of patients who may not be classified as excellent or very good risks from the standpoint of anesthesia is fortunately a minority. It is, however, the recognition of this minority and knowledge of the consequences they may suffer from anesthesia that gives emphasis and importance to its selection. For most surgical patients the most convenient method or one the surgeon and anesthetist uses most frequently can be chosen without increasing mortality appreciably. The human organism quickly reorganizes its functional activities to meet emergencies and to withstand excessive burdens placed upon it. The anesthetist who uses almost any of the recognized methods and drugs may depend on this to secure results that will not be severely criticized. It is unlikely, for example, that a surgeon would find the mortality following any group of simple elective operations upon healthy patients differed widely whether he performed them under ether anesthesia by a simple or complicated method, under regional anesthesia, intravenous anesthesia or with the gases. The morbidity statistics might show some advantage of one or another method but even this would depend more upon the skill with which the drug or method was used. For the majority of anesthetic or surgical procedures technical skill is all that is required to have acceptable results. The relative safety of anesthesia and the relative simplicity of most operations favor the anesthetist and surgeon who have mastered the technics. The highly trained specialist is not an absolute essential for satisfactory anesthesia or surgery of the good risk patient who is undergoing an elective uncomplicated operation. The advantage that he can bring :

patients is the ability to recognize those who are not good risks and the experience and training needed to cope with unpredicted complications in the healthy and the sick when they arise. For patients with serious physiological disturbances or those who require special complicated manipulations, the more experience, judgment and training that the surgeon and anesthetist can bring to the selection and execution of procedures to effect a therapeutic result the less morbidity and mortality may be expected.

Arguing the merits of one drug or another by quoting data on mortality and morbidity immediately following operation too often has little significance. The many factors involved are usually disregarded or the reported number of cases are too few for statistical analysis. The statistical method of evaluating the effects of drugs or methods will not be criticized if it is properly applied. Very few such studies have appeared, however, largely because a sufficient number of observations with the necessary data have not been recorded. To have significance, cases studied need to be analyzed in groups of tens of thousands, not hundreds. *If a method has been used in a limited number of cases and found to have undesirable or even fatal consequences by one group of clinical investigators, one need not be amazed to find the same drug or method used elsewhere to the satisfaction of the surgical team. Requirements of one group of surgeons may differ considerably from those of another. The anesthetist's experience or dexterity with certain methods may vary widely with his ability to use different procedures. It is unlikely that anesthetic drugs and technics will have proper evaluation if the arguments are settled by the experiences reported from any single group or even several groups of observers.*

Another common argument for or against one drug or method may be based on results with it contrasted with those from an entirely different procedure. For example, the merits of regional or spinal anesthesia are often contrasted with those from intravenous or inhalation anesthesia. It rarely happens that the anesthetist who prefers any one system of anesthesia will have used another in comparable cases extensively enough to formulate a definite opinion on the merits of both. For example, if spinal anesthesia is regularly used for cholecystectomy in one clinic the experience with ether for the same group will probably be too limited for evaluation. Systems of anesthesia are frequently favored to satisfy some special requirement of the individual clinic. Fully qualified anesthetists are not available in many places to permit a wide range of choice from among the many methods that now have a merited place in the practice of the specialty. Moreover, if all surgical teams could have an anesthetist fully experienced with all systems, drugs and *methods* recommended, it would not follow that the surgeon could readily adapt

his manipulations to the resultant anesthesia. The surgeon who has satisfactory results with some particular procedure has adjusted his operating to it. For example, few surgeons find any criticism with operating conditions while working in the upper abdomen during well administered spinal anesthesia. If, however, many of them were forced to operate with splanchnic block and local infiltration in accordance with the custom in some leading foreign clinics, they might have their results as well as their composure disturbed.

What can be done in selecting anesthesia is to consider the drugs and methods which are familiar to the anesthetist on a basis of their effects in the presence of the disturbed or anticipated physiological disturbances of the patient and the technical requirements of the surgery proposed. Plan prophylactic and therapeutic measures for complications that may likely occur during and after the particular operation and choose the drug and method that can be used successfully with the least danger to the patient.

COMPLICATIONS AND THEIR MANAGEMENT

Emesis.—It is well for the anesthetist to anticipate complications that may be expected during abdominal operations. Emesis might be cited as an example. It should be assumed that every patient not properly prepared for operation or those whose gastrointestinal derangements favor the retention of stomach or intestinal contents, will have dangerous emesis during induction or maintenance of anesthesia. The psychic disturbances, the effects of opiate medication, the stimulating action of many anesthetic drugs, transient asphyxia, manipulations of the stomach and intestines are factors that may favor a high incidence of emesis in such patients.

The aspiration of vomitus during anesthesia is responsible for many preventable deaths every year. The anesthetist is obligated to employ a procedure which he is sure will eliminate aspiration of vomitus if emesis occurs, for all patients not properly prepared for surgery. Such a procedure may involve washing out the stomach contents before anesthesia is induced. When this or any other practice is done to safeguard the patients from the effects of anesthesia it becomes a part of the anesthetic procedure and constitutes a consideration in the selection of the drugs and methods employed. More emphasis can be given to the preparation than to the agent when complications from emesis are seriously feared.

If inhalation anesthesia is proposed a drug such as cyclopropane has advantages because of the rapidity of induction without asphyxia and lack of irritation or excess mucous secretion in the upper gastrointestinal tract. Another safeguard of importance is the prompt introduction of an

endotracheal airway that may be made leak-proof at the trachea. When some form of regional anesthesia is selected the patient retains his natural protection against aspiration of vomitus unless his reflexes are severely depressed by medication or shock. The high probability of emesis during anesthesia for unprepared patients may be frequently a good indication for regional anesthesia.

Convulsions.—Convulsions during anesthesia are not rarely a factor in the mortality of certain uncomplicated abdominal operations; appendectomy, for example. Although not common enough to be anticipated in even a moderate percentage of any operative procedure and despite the lack of agreement as to their cause, convulsions are a complication most often when some of the following circumstances are noted: Young adults and children with an infection causing an increase in body temperature, dehydration, hot external environment; atropine medication; inhalation anesthesia; disturbances in oxygen-carbon dioxide transport. Such circumstances may indicate the use of nerve block, for example, spinal anesthesia for appendectomy, rather than ether by the carbon dioxide absorption technic. Or a delay in operation to treat dehydration may be called for.

Heat Retention.—Heat retention is a complication given too little consideration, especially in temperate climates during hot weather. Rapid respiration, increased body temperature, muscle twitching, dry skin and convulsions rapidly succeeding to shock are the most common manifestations. It is our belief that the closed system for inhalation anesthesia, causing the patient to respire a heated, humid atmosphere, the use of several heat retaining drapes, the lack of ventilation in operating rooms and the use of atropine or similar drugs are factors to consider in reducing the incidence of heat retention.

Surgical Shock.—Surgical shock must be anticipated during any extensive abdominal manipulation, but wide differences of opinion have always existed as to its bearing on the selection of anesthesia. The rule or warning is frequently found in textbooks and journals that general or inhalation anesthesia should not be employed for patients in shock. Anesthetists who believe this firmly will not hesitate to produce deep inhalation anesthesia in patients having operative procedures that may reasonably be expected to cause severe hemorrhage or shock. It is admitted, of course, that the time interval may be an important factor in the shocked patient's resistance to anesthetic drugs—and that patients who may be expected to be in shock during the course of an operation have the advantage of prophylactic intravenous therapy. However, the fact that clinical experience and laboratory experiments have demonstrated conclusively that certain anesthetic procedures

are detrimental during shock should be given more consideration in selecting anesthesia for patients when shock is anticipated.

It is well known, for example, that an animal during high spinal anesthesia will die from much less blood loss than will an unanesthetized control. Similarly, shock is more readily induced in an animal during deep ether anesthesia. The anesthetist should keep in mind that the shocked patient, whether shock occurs during or before operation, is suffering from hypoxia which is enhanced by inadequate ventilation due to rapid shallow respirations. Also, that pain and psychic factors may play a major role in producing shock. The patient needs, in addition to an adequate circulating blood volume, more efficient respiratory exchange of an atmosphere with a high oxygen content, the elimination of pain and adequate psychic sedation. It may not be advisable to attempt to secure the latter two of these needs with the opiates in amounts that interfere further with respirations. Inhalation anesthesia can be given safely with cyclopropane under these circumstances. It has the advantage of producing unconsciousness in very low dilutions, is rapidly controlled and quickly eliminated. Respirations may be improved by positive pressure during the inspiratory phase and oxygen given as desired. It would be inadvisable, of course, to push anesthesia to produce relaxation if this were needed. Curare, muscle infiltrations or nerve block can be used for this purpose.

There is no experimental evidence to prove that first plane cyclopropane anesthesia during shock or hemorrhage is dangerous and there is a considerable clinical experience to give the impression that it is satisfactory. It is the recommendation here that when shock occurs during anesthesia, the anesthetist should provide the patient with a high oxygen atmosphere, that if intravenous anesthesia is being used it be discontinued, that any inhalation anesthetic agent be eliminated as quickly as possible, and that, when needed to maintain unconsciousness, first plane cyclopropane anesthesia be employed.

Other Circulatory Crises.—There are other circulatory crises, apart from shock, of interest and importance which may develop during abdominal operative procedures. These are neurogenic in origin, reflex in propagation and potentially dangerous if unrecognized or neglected. Reference is made to the hypotension, bradycardia and apnea produced on occasion by traction on the hollow organs of the abdominal cavity. The traction or celiac plexus reflex requires prompt therapy to obviate the sequelae associated with significant prolonged hypotension. Corrective measures are relatively simple and consist of infiltration of the celiac plexus with procaine or the administration of small doses of ephedrine intravenously. No patient is immune from this complication regard-

less of anesthetic agent or technic employed. It is indeed fortunate that adequate therapy is readily available since satisfactory recovery in those patients who can ill afford circulatory depression may be more effectively guaranteed.

Psychic Trauma.—In accord with the increasing appreciation in all special practices of medicine of the importance of psychodynamic factors in disease or injury, it has become fairly well established that most patients subjected to operative procedures of any magnitude deserve the benefits of oblivion to the traumatic experiences of the surgical amphitheater. The increased utilization of inhalation anesthesia for abdominal surgery, undoubtedly encouraged in part by the availability of curare for relaxation of abdominal muscles, is a reflection of this attitude in many clinics. Although the popularity of spinal analgesia has suffered somewhat, it still enjoys widespread usage, significantly modified by the more frequent application of supplementary drugs which produce narcosis. Dilute solutions of sodium pentothal or light cyclopropane anesthesia have been of enormous value in making intra-abdominal surgical therapy during spinal anesthesia more acceptable to patients who understandably are distressed by the working sounds of the surgical team.

Intestinal Obstruction.—Despite the important progress made in the understanding of the pathological physiology, preoperative preparation, and principles of surgical attack upon intestinal obstruction, the anesthesiologist is still confronted here with his most vexing difficulty in the management of abdominal operative procedures. It is true, of course, that the problem is not the same when adequate decompression and proper electrolyte balance and circulating fluid requirements have been established prior to the induction of anesthesia. However, this has not uniformly been possible in the experience at this institution. The patient who cannot be prepared completely is one who is actually or potentially in shock from dehydration, may aspirate intestinal contents, and for reasons poorly understood at the present time may expire suddenly early in the anesthesia period. These difficulties are entirely aside from the serious technical difficulty which distended intestinal loops afford the unhappy operator. The precarious state of the circulation and the possibility of rupture of compromised intestine suggest the inadvisability of spinal analgesia during these circumstances. Inhalation anesthesia, with an endotracheal catheter particularly with cyclopropane, is relatively safer, but is far from adequate in the management of decompressed intestinal obstruction. The nature of the gravity of the situation may be appreciated readily when it is realized that the largest single cause of death on the operating table here is inadequate preparation of the patient with intestinal obstruction. It is apparent that further study

of the role of anesthesia in the hazard of surgical therapy of this lesion is mandatory.

SUMMARY

A commentary on the problems of anesthesia during abdominal surgery is presented. Stress is placed upon the futility of establishing fixed routines in the selection of anesthesia for the surgical therapeutics of abdominal lesions. It is strongly suggested that the anesthetic management be flexible and in keeping with the importance of individualization for the needs of the patient subjected to operation.

The management of several of the serious complications occasioned by anesthesia and surgery during abdominal procedures follows certain established principles.

RECENT ADVANCES IN THE CHEMOTHERAPY OF SURGICAL INFECTIONS

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RECENT progress in the management of surgical infections has made yesterday's miracle into the commonplace reality of today. Because of the rapidity of this advance, it seems proper at intervals to make an evaluation of some of the more recent additions to knowledge in this field. In this way one hopes in some degree to separate those antibacterial measures which are fulfilling their original promise of usefulness from those which appear in the full light of experience and surgical judgment unsuited for the treatment of infections in man. In the present paper the term, "chemotherapy," includes the so-called antibiotic agents as well as the chemical substances of more certain composition such as the *sulfonamides*.

Developments in the chemotherapy of surgical infections may pertain to new chemical agents or to improved methods of using the materials already at hand. Some of the newly produced agents will, no doubt, prove to be useful therapeutic agents. As yet, however, the amount of experimental and clinical work relating to these compounds is often not sufficient to permit accurate appraisal of their worth. This discussion will consider the *sulfonamides*, penicillin, streptomycin and bacitracin and some of the more advantageous methods of employing these drugs in combating surgical infections. Changes in methods include increased dosages, different dosage schedules, different routes of administration, and various vehicles for the drugs.

CHOICE OF DRUGS

Formulation of a plan of antibacterial therapy must be based on a careful analysis of the type of infection to be treated or prevented. The ideal antibacterial agent is one which possesses a broad range of activity against all of the *pathogenic bacteria which may exist in the body* and yet is devoid of toxic action on the body tissues. Since this ideal substance is as yet unknown, it is essential, in using effectively the drugs which are available, to determine the nature of the infecting organism and then to select the particular therapeutic agent most likely to attack

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this bacterium within the infected anatomical region. If such careful bacteriological studies cannot be carried out, then the decision must be reached by inference, and the choice of agent will be made on the basis of clinical judgment as formed through awareness of probabilities.

Tables 1 to 3 show in general the range of activity of the agents under discussion. All strains of a given organism, however, are not uni-

TABLE 1

BACTERIA SUSCEPTIBLE IN VITRO TO STREPTOMYCIN

<i>Aerobacter aerogenes</i>	<i>Pasteurella tularensis</i>
<i>Alcaligenes faecalis</i>	<i>Proteus morganii</i>
<i>Brucella abortus</i>	<i>Proteus vulgaris</i>
<i>Brucella melitensis</i>	<i>Pseudomonas aeruginosa</i>
<i>Eberthella typhosa</i>	<i>Salmonella species</i>
<i>Escherichia coli</i>	<i>Shigella species</i>
<i>Hemophilus ducreyi</i>	<i>Streptobacillus moniliformis</i>
<i>Hemophilus influenzae</i>	<i>Actinomyces bovis</i> *
<i>Hemophilus pertussis</i>	<i>Bacillus anthracis</i> *
<i>Klebsiella ozenae</i>	<i>Corynebacterium diphtheriae</i> *
<i>Klebsiella pneumoniae</i>	<i>Diplococcus pneumoniae</i> *
<i>Neisseria gonorrhoeae</i> *	<i>Mycobacterium tuberculosis</i>
<i>Neisseria intracellularis</i> *	<i>Staphylococci</i> *
<i>Pasteurella pestis</i>	<i>Streptococci, hemolytic</i> *
	<i>Streptococci, nonhemolytic</i>

* Penicillin-sensitive

TABLE 2

ORGANISMS SUSCEPTIBLE TO PENICILLIN

<i>Actinomyces</i>	<i>Neisseria gonorrhoeae</i>
<i>Bacillus anthracis</i>	<i>Neisseria intracellularis</i>
<i>Bacillus subtilis</i>	<i>Spirillum minus</i>
<i>Borrelia novyi</i>	<i>Staphylococcus albus</i> (some strains)
<i>Clostridium botulinum</i>	<i>Staphylococcus aureus</i>
<i>Clostridium perfringens</i>	<i>Streptobacillus moniliformis</i>
<i>Clostridium septicum</i>	<i>Streptococci (micro-aerophilic)</i>
<i>Clostridium tetani</i>	<i>Streptococcus pyogenes</i>
<i>Corynebacterium diphtheriae</i>	<i>Streptococcus salivarius</i>
<i>Diplococcus pneumoniae</i>	<i>Treponema pallidum</i>
<i>Leptospira icterohaemorrhagiae</i>	<i>Virus of psittacosis (ornithosis)</i>
<i>Micrococci (some strains)</i>	

formly susceptible to the same agents, and this makes it highly desirable to test the sensitivity of each particular organism against the drug which is to be used. Since treatment should usually be commenced at once, the results of this laboratory test will serve as a check on the accuracy of the choice of drug which has been made.

Factors inhibiting the activity of the drugs under consideration some-

times play a part in choice of agent. The bacteriostatic activity of the sulfonamides is destroyed by inhibitors found in wound exudates, ne-

TABLE 3
ANTIBACTERIAL SPECTRUM OF BACITRACIN
(Preliminary Survey)

Organisms	Sensitive to Bacitracin (in units)*	Resistant to Bacitracin (in units)*
<i>Aerobic Bacteria</i>		
Hemolytic streptococci		
Group A, B, C, G.	0.008-0.0005	
Group D.	3-0.008	
Nonhemolytic streptococci	3-0.02	
Pneumococcus		
Type I, II, III, XVIII	0.008-0.002	
Type XXXII	0.015	
Staphylococci (coagulase)	2.5-0.05	
Other micrococci.	2.5-0.005	
Diphtheroids.	0.005-0.003	
Clostridium diphtheriae	0.015-0.001	
Meningococcus	0.01	
Gonococcus	0.008	
Bacillus anthracis	8-12.5	
Bacillus subtilis group.		100
Escherichia coli.		100
Aerobacter aerogenes		100
Aerobacter cloacae		100
Proteus		100
Pseudomonas aeruginosa.		100
Alcaligenes faecalis.		100
Eberthella typhosus		100
<i>Anaerobic Bacteria</i>		
Clostridium welchii.	0.025-0.002	
Clostridium septicum	0.008-0.002	
Clostridium sordellii	0.01-0.005	
Clostridium novyi	0.01	
Clostridium tetani	0.01-0.006	
Clostridium histolyticum	0.01-0.001	
Nonhemolytic streptococci	0.01-0.005	
Micrococci	0.05-0.008	
Diphtheroids	0.003	

* One unit is the amount of antibiotic which can be diluted 1000 times and still inhibit the growth of a test strain of beta hemolytic streptococcus.

erotic tissues, and pus. The "peptones" present in these materials have been shown to inhibit the sulfonamides in vitro,²⁵ and the inability of

sulfonamides to penetrate pus and necrotic tissue has been a common observation. The value of the sulfonamides is further lessened by the frequent occurrence in surgical infections of the organisms not susceptible to sulfonamides. Neither penicillin, streptomycin nor bacitracin is inactivated by pus or necrotic tissue. Certain organisms, however, especially the gram-negative bacilli and most of the gram-positive spore-forming bacilli, are capable of inhibiting the bactericidal activity of penicillin through production of a penicillinase.^{50, 1, 45} In mixed culture with penicillinase-producing organisms, even susceptible staphylococci and streptococci may proliferate unimpaired in the presence of penicillin. No comparable enzyme capable of inhibiting bacitracin⁴⁵ or streptomycin⁴⁴ has yet been described.

One limitation of streptomycin is the *frequent occurrence of insensitive organisms* in an infection which appears primarily to be clearing under streptomycin therapy. This has been thought to be similar to the phenomenon observed less often in connection with penicillin, and explained on the basis of the initial presence of a few resistant mutants whose progeny survive and finally predominate through a process of genetic transmission and continuous selection.⁴⁵ Subsequent experimental work demonstrates the same manner of evolution of strains resistant to streptomycin.²

Toxic reactions to these agents may be severe. The toxic renal and hypersensitivity reactions to systemically distributed sulfonamides are too well known to require discussion. Toxic sequelae of penicillin therapy are comparatively rare, and most commonly take the form of minor cutaneous and febrile reactions of a presumably allergic nature. However, *severe varieties of such reactions have been described.*

The most serious toxic effect of streptomycin is that on the eighth nerve. The harmful effects of streptomycin on the otic mechanism are a function of dosage and duration of administration of the drug. As the dosage increases, the percentage of patients showing vestibular disturbances rises, and at the higher dosage levels auditory involvement is more apt to occur.²⁰ In avoiding otic complications, Fowler recommends that dosage be figured in terms of milligrams per kilogram of body weight per day rather than simply in grams per day.²⁰ The dosage combining good therapeutic effectiveness for most conditions (excluding military tuberculosis and tuberculous meningitis) with minimal eighth nerve damage appears to be 20 mg. per kilogram per day.²⁰ The practice of administering the entire amount for the day in one or two large doses is considered more likely to cause otic injury than if smaller fractions are given at about three hour intervals.¹⁹ Careful histologic studies of all known vestibular and auditory tracts and nuclei failed to identify the site of damage to the otic mechanism.²⁰ Audiogram testing before in-

stitution of therapy serves as a base line for subsequent testing of hearing loss. Quantitative caloric tests will detect early damage to the labyrinth mechanism, as will the development of nystagmus on lateral gaze.¹⁸ Prompt cessation of streptomycin therapy results in arrest of otic damage, and in some instances considerable recovery occurs, particularly through development of compensatory visual and proprioceptive devices.

The toxicity of bacitracin cannot be fully evaluated until a pure crystalline preparation is available. The presently available amorphous material has not caused toxic effects when used locally or topically. Its systemic administration, however, has been associated with manifestations of lower nephron nephrosis in a significant proportion of treated cases. In most instances these manifestations have consisted of mild or moderate degrees of albuminuria and cylindruria of brief duration without evidence of ominous kidney damage. On a few occasions significant impairment of phenolsulfonphthalein excretion and elevation of blood urea nitrogen have been produced. In the most severe reaction observed at the Presbyterian Hospital, the patient developed oliguria (45 cc. of urine in twenty-four hours) and elevation of serum urea nitrogen to 127 mg. per 100 cc. Improvement of renal function took place following cessation of intramuscular bacitracin therapy.⁴⁴ It is to be emphasized that this toxicity has been observed after use of an impure preparation. Whether such nephrotoxicity is a part of the antibacterial fraction of the present material cannot be stated until the chemical nature of the active antibiotic agent is known and a pure preparation is available for study.

The antibacterial spectrum of bacitracin is approximately that of penicillin, with an important advantage over penicillin as regards variations of susceptibility of different strains of a given organism. That is to say, many organisms ordinarily considered sensitive to a given antibiotic agent develop strains which are resistant. Among groups of organisms thus far studied, more organisms have been penicillin-resistant and bacitracin-sensitive than have been bacitracin-resistant and penicillin-sensitive.⁴⁵ This fact plus the absence of any known inhibitor factors makes bacitracin a useful drug to employ in those infections which do not respond to penicillin either because of strain insusceptibility or because of the presence of penicillinase-producing organisms.

MAINTENANCE OF PLASMA LEVELS OF ANTIBIOTICS

In early work with penicillin it was assumed that plasma penicillin concentration should be maintained constantly at or above the level at which the organism under attack was killed by penicillin *in vitro*. This

concept was taken by analogy from the experience with sulfonamides where unremitting maintenance of effective levels was demonstrably required. Apparent confirmation of this principle has come from experimental work establishing clearly: (1) that penicillin is actively bactericidal *in vitro*,^{13, 14, 22, 24, 25, 26, 27} provided an adequate concentration of the drug is developed and (2) that the rate of bactericidal action is accelerated by increase of penicillin concentration up to a maximally effective concentration.¹⁵

The maintenance of relatively constant bactericidal penicillin plasma levels has been accomplished with varying degrees of success by several means: (1) continuous intravenous administration, (2) continuous intramuscular administration; (3) frequently repeated intramuscular injections, (4) a slowing of absorption of penicillin by use of slowly dispersed vehicles, and (5) retardation of renal excretion of penicillin.

An apparatus has been constructed for the slow, continuous administration of the drug in solution either intramuscularly or intravenously. The day's dosage is dissolved in 2 cc. of distilled water and slowly injected at constant rate over the twenty-four hour period.⁸

Retardation of absorption has been accomplished by use of penicillin in an oil and beeswax base²⁸ and procaine penicillin in oil.^{23, 5} The oil and beeswax base has the disadvantages of causing local pain after injection, appreciable incidence of generalized allergic reactions, and occasional production of sterile abscesses. Early reports indicate procaine penicillin in oil to be free from these disadvantageous features.

Slowing of the rate of excretion of penicillin has been achieved by use of caronamide.^{4, 5} This compound has been shown capable of preventing loss from the body of 80 per cent of the penicillin normally excreted by the kidneys. The mode of action of caronamide is a blocking of the renal tubular transport mechanism by which most of total urinary penicillin is excreted. The 20 per cent of total urine penicillin lost by glomerular filtration is unchanged. The renal function returns to normal after caronamide administration is stopped.^{4, 5} Now that penicillin is abundantly available, caronamide seems only infrequently indicated. Its use should be considered in (1) desperately serious infections caused by organisms relatively insensitive to even high concentrations of penicillin, (2) the oral use of penicillin. A real disadvantage of caronamide administration is the large amount of the drug required to bring about significant retention of penicillin and subsequent elevation of plasma level.

It now appears that continuously sustained elevation of plasma penicillin levels is not essential to the successful treatment of most infections due to susceptible pyogenic organisms. It has been shown that when susceptible organisms have been exposed for brief periods to

penicillin in vitro, the organisms which survive do not begin to multiply until some time has elapsed after neutralization of the penicillin with penicillinase.⁵¹ When susceptible organisms were exposed to penicillin in vivo (mice), there was a persistent antiparasitic effect of the penicillin long after its disappearance from the plasma.^{42, 51}

The continuing deaths among the bacterial population after disappearance of penicillin from the blood stream is probably the result of a combination of several factors: (1) some organisms are injured beyond recovery by the penicillin before its disappearance; (2) persistence of penicillin in the tissues after it is no longer detectable in the plasma; (3) synergistic action of body defenses and antibacterial effects of the drug.¹³

To see if the same considerations obtain in the case of streptomycin, this agent was used to treat *Klebsiella pneumoniae* peritonitis in mice. The results from administration of the drug every four hours were not significantly better than those when the interval between doses was eight hours, and only slightly better than when a schedule of three doses at twenty-four hour intervals was followed.⁶³

Thus the trend has been away from the complicated and difficult means required for continuous maintenance of bacteriostatic plasma antibiotic levels and toward the more practical scheme of larger doses at intervals of eight to twelve hours. So far, clinical experience has seemed to justify this trend.¹

The high, relatively constant plasma antibiotic levels are still used for the treatment of subacute bacterial endocarditis, bacteremia, severe, extensive rapidly invasive infections, and in other conditions where the patient's life or limb seems to be endangered by the infectious element of his disease. In such conditions large doses are given at three hour intervals. In general, doses have tended to grow larger in recent years, as the antibiotics have become more abundant and less expensive. In the case of penicillin another contributing factor toward increasing doses has been the relative absence of toxicity of this drug.

PRODUCTION OF HIGH ANTIBIOTIC CONCENTRATIONS LOCALLY

Several different routes of administration have been investigated in an effort to produce higher tissue concentrations of antibiotic drugs intermittently than is possible by the routes commonly employed. The *intra-arterial injection* of penicillin has been advocated in the treatment of extremity infections, and the local or transcutaneous administration of antibiotics is proving to be of considerable value.

Intra-arterial administration of penicillin has been shown experimentally to maintain higher concentrations of the injected substance in

the extremity for longer periods than can be achieved by either intramuscular or intravenous administration.²⁰ Other workers, however, consider the intra-arterial administration of penicillin no more effective than other systemic methods,²¹ at least as far as clinical response is concerned. The arterial route requires further study, but there would seem to be many therapeutic arguments in its favor.

The *local injection* of antibiotic agents at the site of infection is enjoying increased usefulness as previous prejudices against infiltrating infected tissues have been overcome by experience. As early as 1943 the Floreys were treating superficial pyogenic infections successfully by the direct surface application of penicillin solutions to infected wounds,¹⁴ and more recently it has been observed that the antibiotics may be injected directly into infected soft tissues.

The method thus far has proved most effective in relatively superficial infections^{17, 22, 23, 47, 48, 52, 53, 62} Concentrations ordinarily used are as follows:

Penicillin	1000-5000 units per cc. Occasionally 25,000-30,000 units per cc
Streptomycin	200-500 units per cc
Bacitracin	500-1000 units per cc.

The respective agents are dissolved in 1 or 2 per cent procaine hydrochloride solution to minimize local pain.

I. Cellulitis without abscess formation. The involved tissues are infiltrated with the antibiotic solution, the higher concentrations being used for more fulminating infections. This treatment is repeated at twelve to twenty-four hour intervals depending on the severity of the process until subsidence is evident—usually not more than two to three days being required.

II Cellulitis with abscess. Pus is evacuated, using syringe and needle, and final choice of antibiotic is dictated by culture and sensitivity studies. The cavity is irrigated with antibiotic solution at intervals of two to twenty-four hours. If the abscess is large and the patient is ill, a small plastic catheter brought out through the dressing permits frequent instillation of antibiotic into the cavity. Where surrounding induration is extensive (as in carbuncles), the inflamed tissues are infiltrated with antibiotic solution at twelve to twenty-four hour intervals in addition to the local instillations via catheter into the cavity.

III. Involvement of serous and synovial cavities. In acute tenosynovitis, acute bursitis, suppurative empyema^{20, 2} and suppurative arthritis, it is usually unnecessary to perform orthodox incision and drainage, particularly if treatment can be carried out within a week of

the onset of the disease. Evacuation of pus and application of an effective antibiotic solution directly to the site of infection can be performed, using needle and syringe in most instances. Good results are not anticipated if the organism is strongly resistant to the available antibiotic agents. If the empyema is multilocular, the local treatment may fail because of inability to discover and enter all loculations. It is to be emphasized that re-expansion of the lung, combined with sterilization of the pleural space, is the aim of treatment of empyema. No case can be considered cured until the lung is expanded and the pleural space obliterated.⁴⁰

Systemically administered antibiotic is used as a supplement in most cases of group III and in any instance in which the systemic reaction is severe or the infection threatens to involve a vital structure by direct extension.

Advantages of the local method over systemic dosage appear to be as follows: (1) The higher tissue concentration obtained by local as compared with systemic administration makes variations of strain susceptibility a less critical limiting factor of success. (2) Incisions are minimized or even obviated in many instances. (3) Smaller total dosage of penicillin effects a financial saving which is important in some cases. (4) Many infections which would necessitate hospitalization under orthodox therapy can be treated successfully on an outpatient basis by local antibiotic therapy.

Conditions which have responded especially well are infections about the face, carbuncles, breast abscesses, and infections of the hand and fingers, including acute suppurative tenosynovitis and pulp space infections of the fingers. In treating breast abscesses by this method, it is essential to discover and irrigate individually each separate loculation. If a single closed pocket of a multiloculated abscess is neglected, the treatment may not succeed. It has been interesting to observe that local edema and induration usually persist for many days after the active infection has become checked by direct injection of an antibiotic. This is especially noteworthy in breast abscess, where the residual process often resembles a breast tumor.

The *intrathecal administration* of antibiotics for surgical infections of the central nervous system is a more widely accepted method of local antibiotic therapy. In some varieties of meningitis, such as the pneumococcal and tuberculous types, intrathecal administration is essential if good results are to be obtained.

The value of penicillin as an adjunct to the treatment of infections of the hand and fingers has been studied.^{7, 10, 11, 67} One group has treated infections of the hand by the unorthodox method of meticulous excision of devitalized tissues from the primary site of infection and primary

closure of the wound. Penicillin was used both locally in the wound and intramuscularly. The healing time was significantly reduced by this method.²²

CHEMOTHERAPY IN LARGE BOWEL SURGERY AND PERITONITIS

Antibiotic agents are used in association with alimentary tract surgery in order to minimize the consequences of fecal soiling of peritoneal and wound surfaces either from the operative procedure or from subsequent leakage at the anastomotic site, also in the therapy of established peritonitis

To date the oral administration of a nonassimilated sulfonamide such as succinylsulfathiazole remains the most effective means of diminishing the bacterial count of the intestinal contents in preparation for elective surgery.²³ The use of oral streptomycin for this purpose has been largely abandoned for the following reasons:²⁴ (1) The striking reduction of fecal bacterial count seen during the initial forty-eight hours of treatment in about 50 per cent of cases is usually not maintained. (2) As the bacterial count rises after this early fall, a large proportion of the surviving organisms display high resistance to streptomycin. A subsequent peritoneal infection due to these resistant bacteria would probably not respond to streptomycin therapy (3) In many cases streptomycin has shown powerful antibacterial properties at lower concentrations, but a paradoxical loss of activity as the concentration is increased.

For prophylactic antibacterial purposes after elective alimentary tract surgery, systemically administered sulfadiazine, penicillin and streptomycin remain the most effective measures. Because of its toxicity streptomycin can be reserved for those situations where the threat of infection is most ominous.

A mixture of sulfamylon (marfanil) and streptomycin has been demonstrated to be bactericidal to a variety of organisms when applied topically.^{25, 26, 27} Freshly contaminated experimental wounds with large amounts of necrotic muscle developed only minimal or no infection if thoroughly lavaged and infiltrated with this combination of drugs immediately after contamination. When such topical application was delayed for three hours or more, infection occurred.

Following operations opening the alimentary tract, the sulfamylon-streptomycin mixture has been used as a topical irrigating fluid for peritoneum and abdominal wall wounds. In preliminary studies this measure appears to be an effective means of avoiding local infection due to fresh contamination of wounds with alimentary tract organisms²⁷ and is being studied further.

The control of established peritonitis by modern antibacterial agents

supplementing intelligent operative and supportive measures provides one of the most spectacular advances in present-day surgery.

In treating experimentally induced peritonitis with various antibacterial agents in various combinations and by different routes of administration, best results were obtained using both penicillin and streptomycin in combination intramuscularly.⁴⁹ All animals so treated survived, whereas all controls died speedily. Penicillin X, surprisingly, seemed more effective than penicillin G. The systemic use of penicillin and sulfadiazine in combination was not tried. In the treatment of peritonitis, penicillin dosage should be large—up to 1,500,000 units per day, but streptomycin dosage should not exceed 20 mg. per kilogram of body weight per day, and should be given at about three hour intervals.

CHEMOTHERAPY IN PULMONARY SURGERY

The incidence of empyema following pneumonectomy, lobectomy, pulmonary decortication, esophagectomy and the like has been minimized by prophylactic systemic antibiotic administration, but the last two years have brought forth no noteworthy additions to knowledge in this field, save with reference to tuberculosis which will be considered later. The local antibiotic treatment of empyema has been mentioned above.

The principle of topical application of antibacterial agent has for some time been utilized in the treatment of bronchiectasis and lung abscess by aerosolization. Recently the bibliography of this subject has been reviewed and report has been made of a group of cases treated with success.⁶³

Lung abscess has been treated by the intrabronchial instillation of penicillin via a plastic tube, the patient being placed in the position to encourage the gravity flow of the penicillin into the abscess cavity.⁶⁰ Of eleven patients, ten were cured; one patient 69 years of age, who was in bad general condition, died.

CHEMOTHERAPY IN BONE LESIONS

Pyogenic infections of bone have shown rapid subsidence on systemic antibiotic therapy in a large proportion of cases. A recent review of 138 cases of acute hematogenous osteomyelitis in children points out the rapid and dramatic subsidence and abortion of the bone infection before changes leading to chronicity can occur.⁶⁴

Compound fractures treated by internal fixation require powerful prophylactic systemic antibiotic protection after operation. Penicillin is the drug of choice, but streptomycin may also be given for a few days

when unusually severe contamination has existed. In the uncommon case where drug hypersensitivity on the part of the patient prevents the use of penicillin, bacitracin may be employed as an alternative, with due regard for its toxic potentialities

STREPTOMYCIN IN TUBERCULOSIS

It is difficult to assess the value of streptomycin as an adjunct to the management of tuberculosis in general because of the relatively short time the drug has been used in the treatment of this very chronic disease. While more experience is necessary for an accurate appraisal of ultimate worth, certain observations have been made.

"Under certain circumstances, streptomycin appears to lessen or prevent further multiplication of tubercle bacilli in the lesions of human tuberculosis, but this suppressive effect is of limited duration. After a few weeks or months of continuous treatment, streptomycin-resistant tubercle bacilli may appear and fail to yield to streptomycin therapy. Fortunately, there are types of tuberculosis in which it appears that only temporary suppression of the infection is necessary in order to permit natural defensive mechanisms to gain ascendancy."¹⁰⁸

The radical excisional treatment of pulmonary tuberculosis is now an established practice. That tuberculous tissue can be traversed at radical operation with relative safety is due largely to the protective action of streptomycin administered systemically in conjunction with the operation. Streptomycin used in this manner may serve either or both of two purposes: (1) preoperative suppression of the active tuberculous process, so that radical excisional treatment may be carried out with greater safety, (2) protection against postoperative "spreads" or reactivation.

The relative importance of these two functions will help determine the duration of streptomycin administration before operation as preparation for operation and the duration of postoperative streptomycin therapy as protection against spread or reactivation. The schedule should be carefully planned in advance so that the maximum total time—preoperative and postoperative—during which streptomycin effect is required preferably does not exceed six weeks. Beyond this period the proportion of resistant as compared to sensitive tubercle bacilli may render streptomycin of little or no value.

Similarly the administration of streptomycin as a supplement to one of the less radical operative procedures as for example, thoracoplasty, is usually undesirable unless a real indication exists; such a measure may leave the patient with resistant tubercle bacilli which will render streptomycin valueless at some later time when more urgently needed,

as with a lobectomy or pneumonectomy.⁴¹ It should be recognized, however, that favorable clinical responses to streptomycin have been obtained in some cases although the tubercle bacilli had already become resistant to streptomycin *in vitro*.

The advent of streptomycin therapy has made it practical to subject the patient with pulmonary tuberculosis to such radical operative procedures as lobectomy, pneumonectomy, pleuropneumonectomy, in the presence of tuberculous empyema,^{61, 62} and excision and primary closure of tuberculous abscesses. Fifty-nine of a group of sixty tuberculous sinuses closed spontaneously under treatment with systemic streptomycin.⁹

The drug is decidedly effective in tuberculous laryngitis and bronchitis,⁵⁶ though some tendency to recur has been noted.

Tuberculosis of the urinary tract was studied with encouraging results.³⁴ On large doses of streptomycin intramuscularly, five of six patients with early tuberculosis of the kidney showed prompt clearing of tubercle bacilli from the urine, and eighteen months later the urine of these five patients is still free from tubercle bacilli. Of ten patients with advanced renal tuberculosis, the tubercle bacilli disappeared from the urine of five. After eighteen months, these five patients still show no tubercle bacilli in the urine and are asymptomatic.³⁴ Other workers report that to date actual arrest of disease has been rare.⁵⁶

The small amount of work done on the use of streptomycin in bone and joint tuberculosis does not permit even tentative conclusions.⁵⁶

SUMMARY

A report is made of recent advances in the treatment of surgical infections by penicillin, streptomycin and bacitracin.

In the present state of knowledge concerning antibacterial agents, it is still important to determine the organism causing the infection under treatment and also to know to which of the available antibiotic drugs the strain of organism is most susceptible.

Factors inhibiting the activity of the drugs under consideration are discussed, as are the importance of resistant strains of organisms and some of the toxic reactions to these agents.

Earlier experience with penicillin and streptomycin indicated that plasma concentration of these drugs should be maintained constantly at or above the level at which the organism under attack was killed by the drug *in vitro*. Subsequent work indicates that the results are essentially the same if the drug is administered in larger doses at intervals of eight to twelve hours instead of being administered by some one of the

more troublesome methods formerly used to achieve high, relatively constant plasma concentrations.

The local use of antibiotic agents in the treatment of surgical infections is gaining increasing acceptance. This method appears to have real advantages over the systemic method of administration and is being further evaluated.

The arterial route of administration of penicillin has been employed to a limited extent, and there is reason to believe it will find increasing usefulness in the treatment of fulminating acute infections of the extremities.

The oral administration of the nonassimilated sulfonamides is still the most effective means of reducing the number of bacteria in the intestinal tract in preparation for elective surgery of the bowel. For several reasons the use of oral streptomycin for this purpose has not proved successful.

For the treatment of established peritonitis the systemic administration of penicillin and streptomycin in combination has achieved spectacular success, when used in conjunction with proper operative and general supportive measures.

Some of the advances in thoracic surgery made possible by the use of modern antibiotic agents are described.

In pyogenic bone infection, the employment of large intramuscular doses of the appropriate antibiotic agent remains the most effective addition to properly timed operative treatment. The timing of operation has been altered by the advent of these agents, and in many cases operation has been obviated.

The use of streptomycin has enabled the thoracic surgeon to traverse tuberculous tissue in the excisional treatment of pulmonary tuberculosis. If the period during which streptomycin is administered exceeds four to six weeks, the increase of the proportion of resistant strains of the tubercle bacillus may render the drug of little or no value. The plan of treatment has to be made with this fact in mind. It is not, however, an invariable rule.

Streptomycin appears as a promising agent in the treatment of urinary tract tuberculosis, but requires further study.

The remarkably effective modern antibacterial agents and the improved methods of using these agents in the treatment of surgical infections constitute an invaluable addition to, rather than a substitute for, intelligent surgical management and thorough application of general supportive measures. The plan of management is directed at care of a patient afflicted with an infection rather than at the chemical therapy of a focus of infection alone.

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PROTEIN NUTRITION IN CANCER

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With the technical assistance of Lilly Schmidt and her staff of biochemists and of Mary Coughlin and Mary Fluellen and their nursing staff

This study deals with two aspects of protein nutrition in cancer: (I) The problem of feeding, and (II) The changes in body constituents having to do with the protein status.

I. THE PROBLEM OF FEEDING

The problem of feeding involves a study of the adequacy of the hospital dietary and of the use of special dietetic regimens.

The hospital dietary was tested under two sets of conditions: (a) a three-day period when the patient was served food routinely prepared in the hospital kitchen and allowed to eat as he pleased and (b) a subsequent three-day period when the patient was urged to eat of the same dietary to the limit of his tolerance. For the sake of brevity, these levels of intake may be termed *the voluntary* and *the suasion levels*. Under both levels, the articles of diet prior to being served were weighed. After the meal, the residue was re-weighed and the ingested caloric and nitrogen values were computed from diet tables. The urine and feces were collected and analyzed according to methods described previously.¹ The averaged values for each of the two three-day periods appear in Table 1.

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TABLE 1

AVERAGE VALUES UNDER THE VOLUNTARY AND SUASION LEVELS OF FEEDING

Group	Case No	Period	Ave. Daily Tot. Caloric Intake	Cal W	Ave Daily Tot. N Intake (gm.)	Ave. Daily Uri. N (gm)	Ave. Daily Fec N (gm)	Ave Daily N Balance (gm.)	Ave. Daily Uri Vol (cc)	Clinical Remarks
Mouth	A1	1st	1170	24.5	4.01	4.68	0.83	-1.53	900	Weight loss 36%*
	"	2nd	1790	37.0	11.12	6.64	0.99	+3.49	1290	
	A2	1st	875	19.5	3.53	3.69	1.06	-1.62	2500	High grade obstruction
	"	2nd	1770	38.0	10.03	4.47	1.06	+4.50	1300	
	A3	1st	1463	27.0	7.31	8.19	0.88	-1.72	975	Weight loss 23.2%
	"	2nd	1815	34.0	14.15	11.34	1.08	+1.73	1650	
Esophag-eal	B1	1st	737	15.0	4.06	5.30	0.28	-1.82	440	Weight loss 35%, marked obs
	"	2nd	1407	28.0	6.52	4.63	0.56	+1.92	670	
	B2	1st	1730	32.0	11.00	5.97	0.74	+4.29	1100	Weight loss 35%
	"	2nd	1983	35.0	12.25	5.73	1.21	+4.91	1100	
	B3	1st	782	16.0	2.84	3.48	0.48	-1.12	410	90% obstruction, wt loss 38%
	"	2nd	1200	25.0	5.23	4.98	0.68	-0.43	520	
	B4	1st	533	22.0	5.25	5.14	0.68	-0.47	500	High grade obstruction
	"	2nd	1310	30.0	12.62	8.99	0.78	+2.85	850	
Gastric	C1	1st	950	24.0	5.31	6.49	1.02	-2.02	600	Weight loss 42%*
	"	2nd	1120	28.0	9.84	7.70	1.02	+1.02	770	
	C2	1st	895	19.4	6.12	6.45	0.92	-1.25	400	60% obstruction, 35.5% wt loss
	"	2nd	1572	34.0	9.43	7.95	0.98	+0.5	1400	
	C3	1st	480	13.0*	3.09†	3.96	0.77	-1.6	610	Weight loss 35.4%.* 85% obstruction
	C4	1st	707	16.0*	5.02†	4.24	1.08	-0.32	630	
	C5	1st	—	—	—	3.08	16.98	—	1500	Weight loss 25%
	C6	1st	—	—	—	4.99	1.13	—	430	Weight loss 27.2%
Colon	D1	1st	—	—	—	5.80	0.48	—	950	Weight loss 14%*
Rectal	E1	1st	803	11.0	10.33	7.49	4.26	-1.42	830	Weight loss 11.3%
	E2	1st	—	—	—	6.93	—	—	775	
Extra-gastro- enteral	F1	1st	1966	35.0	7.15	6.62	1.18	-0.65	1050	Weight loss 15.5%
	"	2nd	2382	43.0	12.46	8.54	1.17	+4.57	200	
	F2	1st	1722	27.0	9.02	7.62	0.82	+0.58	1325	Weight loss 12.7%
	"	2nd	2355	35.0	12.18	7.86	0.82	+3.54	1960	

* Calories lost in vomitus not subtracted.

† Nitrogen lost in vomitus subtracted

Altogether fourteen patients were available for this two-fold study. Twelve of these had cancer of various levels of the gastrointestinal tract.

and two had extra-gastroenteral lesions. The regional distribution appears in Table 1, in which are also included four additional patients on whom only the record of the urinary nitrogen excretion was available.

All these patients except D1 gave a history of weight loss, although the accuracy of the estimated loss was in most cases questionable. From the history of the premorbidity weight and the present weight was estimated the percentage weight loss of fifteen of the eighteen patients in Table 1, twelve of whom were in the feeding study group. Only in four of these cases (C1, C2, B1 and D1) were the weight estimates given complete credence since they were confirmed by members of the family. These are asterisked in the table.

The percentage weight loss in these fifteen cases ranged from 0 (D1) to 42 per cent (C1). All the patients except D1 also showed signs of weight loss, such as looseness of formerly well-fitting clothes and looseness and flabbiness of the skin. In B3, C1 and C3, there was pitting edema of the ankles. In this connection it may be useful to recall that in the records of weight loss compiled by Benedict² on his subject Levanzin and on others, complete starvation in one week caused a loss of from 6.4 to 9.36 per cent of the initial weight in ten experiments; in two weeks, a loss of from 10.05 to 12.9 per cent also in ten experiments; in three weeks, a loss of from 12.75 to 18.73 per cent in seven experiments; and in four weeks a loss of from 16.67 to 21.43 per cent in four experiments. In the subjects of the Minnesota Project,³ there was a loss of 18.7 per cent in twelve weeks and of 24 per cent in twenty-four weeks of semi-starvation. During the latter period the stigmata of protein depletion as brought out in Part II of this paper had already developed to significant extent.

The Voluntary Level of Intake.—*The Caloric Intake.*—It will be seen from the table that the total caloric intakes ranged from 480 to 2380, the per kilogram values being from 11 to 25 calories. If 25 calories are taken as the minimal per kilogram caloric requirement for a patient at rest, in only four (A3, B2, F1 and F2) was this requirement fulfilled. Of the four feeding cases in the gastric group (C1, C2, C3 and C4), only one (C1) approached the requirement level, the other three falling much below.

Urinary Nitrogen.—The average nitrogen excretion of a normal person on an average diet in this country has been stated to be 11.7 gm. daily.⁴ In countries with inferior dietary, it is probably less. In the Bellevue Hospital where the patients were drawn from low economic strata, it rarely exceeded 8.5 gm. daily. In the present series of eighteen, all the values fell below 8.5 gm. If the ranges of output were classified so that a level of from 8 to 10.5 gm. is considered slightly below normal; from 6 to 8 gm., moderately low; from 4 to 6 gm., markedly low and below

4 gm., extremely low; then the nitrogen excretion values in these cases are as follows:

Case A3	slightly below normal
Cases C1, C2, E, E2, F and F2	low
Cases A2, B1, B2, B4, C4, C6 and D1	markedly low
Cases A2, B3, C3 and C5	extremely low

In order to give these values a frame of reference, it may be recalled that in Benedict's subject Levanzin² it took thirty-one days of complete starvation to reduce the urinary nitrogen excretion from an initial value of 11.54 to 6.94 gm during which time he lost 12.55 kg. or 22 per cent (from 60.94 to 47.39 kg.); and 277.32 gm. of urinary nitrogen

Fecal Nitrogen.—Taking 1.5 gm. as the standard level of excretion in the normal individual, the fecal nitrogen values were generally low except in one gastric case (C5) and in the two rectal cases (E1 and E2) in whom there was hemorrhage. The other values are consistent with semistarvation levels of excretion.

Nitrogen Balance—Throughout this first three-day period, the nitrogen balance was positive in only two of the fourteen cases (esophageal case B2 and extragastroenteric case F2). In all the others, the balance was negative. It is possible that in the presence of protein depletion when both the caloric requirement and nitrogen excretion are markedly reduced, nitrogen equilibrium might have been achieved from intakes above 6 gm. of nitrogen, in the presence of adequate caloric intake. However, a combination of caloric and nitrogen adequacy was rarely present. It will also be seen that the negative nitrogen balances were of a low order of magnitude, most values ranging from a fraction of a gram to slightly over 1 gm., only one reaching 2.02 gm. (C1).

Urinary Volume.—Except in three cases in whom the urinary volumes were over 1000 cc. a day, in all the eleven others it was well below. In some instances the volume was reduced to slightly over 400 cc. a day.

COMMENTS.—A number of points emerge from the above analysis which it will be worthwhile to discuss. The first is that, in the presence of a malignant tumor, a patient left to his own devices will not ingest enough calories or nitrogen to keep in nitrogen equilibrium. There seems to be a trend for the intake to be least impaired in the extragastroenteral cases, and more in the gastrointestinal cases. In the latter group the least severe restriction occurred in the oral and rectal cases and the most severe in the gastric group. Whether this pattern holds true only here or more generally, bears further investigation. Needless to say, very low intakes occur in the obstructive cases A2, B1, B3, B4, C2 and C3

Secondly, it is apparent from this low urinary excretion that cancerous

growths are not necessarily accompanied by large nitrogen losses and that in the presence of protein depletion a mechanism of conservation of nitrogen which is at work in noncancerous protein depletion is also operative in the presence of cancer. The "toxic destruction of proteins" reported by Mueller⁵ and by Klemperer⁶ in cancer cases seems rather to be the exception than the rule. Thirdly, the nitrogen excretion in the stool is of a low order of magnitude, unless there is hemorrhage or marked exudate loss, in which event this loss can be larger than the urinary loss. Fourthly, the nitrogen balance is usually negative in spite of the attempt to conserve nitrogen. The negative balance at this time is of a low order of magnitude, but if the same mechanism operates as in the case of simple starvation, it was probably of a higher order in the earlier stages when the body stores were larger. If the body lost steadily over a period of three months, say, 2 gm. of nitrogen a day, the total loss would be 180 gm. of nitrogen which alone would account for 5.4 kg. of tissue.

The Suasion Level of Intake.—This second period started immediately after the end of the first, and in the table is labeled *Second Period*. Among the fourteen patients, the attempt to force the intake of hospital diet by persuasion to the point of positive nitrogen balance was apparently successful in all but five (B2, B3, C3, C4 and E1). B3, C3 and E1 were cases of obstruction and in all of them the attempt to raise the intake provoked vomiting and a greater food revulsion. Among the nine successful cases, two were already in positive nitrogen balance (B2 and F2) and in four (A3, B1, C1 and C2) the positive balance was of such small magnitude (from 0.5 to 1.73 gm.) as to raise the doubt that this positive balance was only apparent, not real. This is so because most sources of error in the nitrogen balance bookkeeping favor the positive side. Among these factors may be mentioned the losses which have not been taken into account; namely, the loss in sweat, in shed hair and epithelium, in expectorations and in the small losses incurred in the process of saving urine and stools.

In the other five cases (A1, A2, B4, F1 and F2) the positive balance was of significantly high magnitude ranging from 2.85 to 4.57 gm. It must be mentioned that the apparent regularity of positive nitrogen balance in these four cases during this study is somewhat deceptive, inasmuch as the appetite is so capricious that three of them subsequently refused feeding the next few days. However, even granting that this positive balance could be maintained at will, from the practical clinical standpoint, even the highest of these positive values, +4.57 gm., is not too useful. Because of the increasing danger of metastasis, a surgeon does not feel safe in assigning more than seven to ten days for this "building-up" process. An organism which has lost 12 kg. for example, has lost theoretically nearly 400 gm. of nitrogen. Seven days of regularly

depositing 4.57 gm of nitrogen daily would restore to the body 32 gm., which is less than 10 per cent of the deficit. Thus the attempt to force-feed cancer patients with hospital food into a clinically useful level of nitrogen balance does not seem to meet with eminent success.

Hyperproteinization.—For the rapid replenishment of such proteins in depleted cancer patients, special protein concentrates and hydrolysates occupy a unique place

A comparison may be made between the ingestion and absorption of meat and of protein hydrolysates. A piece of baked steak weighing $\frac{1}{2}$ pound contains about 7.5 gm. of nitrogen and occupies a volume of about 200 cc., allowing for shrinkage from cooking. It has to be chewed before it is swallowed. It takes ninety minutes after ingestion before 40 per cent and four and one-half hours before 90 per cent of it leaves the stomach.⁷ The alpha amino nitrogen in the blood does not reach peak for two to three hours, after which it takes that much time again to recede to initial level. Because of this delayed emptying and the prolonged hyperaminoacidemia, the sense of fullness and satiety which bars further food intake may persist for four to five hours.

An equivalent amount of protein hydrolysate takes a volume of from 75 to 100 cc. No chewing is necessary and the dose can be drunk in one gulp. Given as a medicine it circumvents anorexia and food repulsion. The amino nitrogen level begins to climb in four minutes and reaches peak in from twenty to forty-five minutes, receding to normal in less than an hour. The sense of fullness and satiety is transient and, even with twice this dose, the blood amino nitrogen level will revert to initial within an hour. Because of these differences it is possible to give much higher nitrogen intake with protein hydrolysates than with conventionally cooked food. Protein concentrates and homogenized meats occupy an intermediate position between cooked meats and protein hydrolysates.

That the administration of a large amount of special protein preparations to protein-depleted patients results in an extraordinarily high deposition of nitrogen and rapid recovery from the depletion was adumbrated in some of the earlier reports from this laboratory,^{1, 2} and has been discussed more fully in a recent communication.³ The level given exceeds that of the traditionally high protein diet of 120 gm. of protein by from 100 to 400 per cent. This massive method of replenishment is advisedly termed "hyperproteinization" in order sharply to distinguish it from the traditional "high protein diet" from which it differs so much quantitatively and in physiological effect.

Generally speaking, protein concentrates may be used where there is no obstruction. The level of intake can rarely be pushed above 350 gm. without causing flatulence and diarrhea. For higher levels, homogenized

meats and protein hydrolysates may be used to advantage. While homogenized meat does not cause diarrhea and is more acceptable, it is much more costly. In obstruction cases with vomiting the product of choice is protein hydrolysates.

In order that hyperproteinization may be used effectively, a number of points must be remembered:

1. The large amount of proteins given must be accompanied by caloric adequacy, otherwise the proteins would be used for caloric needs. In our work from 50 to 60 calories per kilogram have been adequate. This caloric supply is partly given by the protein product, but most by simple carbohydrate, usually dextrimaltose, whose absorption time does not lag materially behind the protein product.

2. Not more than 30 gm. should be given as a first dose. Because of the rapid absorption, higher amounts may lead to an hyperaminoacidemia that provokes vomiting. This vomiting is usually transient, and occurs within the first twenty minutes after ingestion. When the vomitus is analyzed, it is found to contain insignificant amounts of nitrogen, showing that the greater portion had already passed into the duodenum. The vomiting has been interpreted by many as toxic, but since it occurs when the amino nitrogen level passes 9 mg. per 100 cc. and since it is known to occur in intravenous injections, it may well be due to stimulation of the vomiting center. It is because of this emetic effect that hydrolysates must be given in small divided doses preferably at hourly intervals. To be sure, a sudden large access of amino acids into the blood would cause more rapid deamination and spillage in the urine, but a higher amount is also offered for storage and this advantage to the organism would seem to counterbalance the two disadvantages.

3. A high level of nitrogen intake in either protein concentrates or in hydrolysates may provoke diarrhea. This can usually be corrected by the administration of colloidal kaolin or aluminum gel given in tablespoon doses with each feeding if necessary.

The nutritional response of six protein-depleted cancer patients to hyperproteinization is summarized in Table 2. B1, C2, C3, E3 and E4 had the regimen preoperatively, i.e., with the growth in situ. E3 and E4 were again subjected to the regimen after the growth was removed. An additional case, C5, had the regimen only after removal. There were thus eight experiments on the six patients, two of whom (E3 and E4) served as their own controls. It will be seen from Table 2 that the periods of hyperproteinization lasted from five to ten days, that the caloric intake ranged from 50 to 60 per kilogram of body weight; that the nitrogen intake ranged from 27.01 to 53.78 gm. of nitrogen per day, or from 0.45 to 0.79 gm. of nitrogen per kilogram of body weight, that the urinary nitrogen excretion ranged from 10.67 to 16.42 gm. per day, that, except

TABLE 2

THE NUTRITIONAL RESPONSE OF SIX PROTEIN-DEPLETED CANCER PATIENTS TO HYPERPROTEINEMIA

Nutritional Record										Laboratory Record																			
Case No.	Diagnosis	Box Age	Days Treated	Pre Morb Wt	Post Wt	Wt Loss (%)	Post-Treat Wt	Ave Cal Intake per kg	Ave Daily N Intake (gm)	Ave Daily N Intake (Kcal/Wt)	Ave Daily N Urine Out (gm)	Ave Daily Fecal N Out (gm)	Ave Daily N Balance	PV (cc)		PP (gm per 100 cc)		TTP (gm per 100 cc)		Hmt		BV (cc)		RCM (cc)		SCN-S (cc)			
														Pre treat	Post treat	Pre treat	Post treat	Pre treat	Post treat	Pre treat	Post treat	Pre treat	Post treat	Pre treat	Post treat	Pre treat	Post treat	Pre treat	Post treat
B1	Recurrent Ca-Oesoph (in situ)	M 57	6	72.73	47.60	34.5	49.8	60	37.73	0.79	10.67	1.00	+16.95	2681	2620	6.65	25	178	183	35	37	4125	4034	1444	1715	20650	440	Total	440
C2	Adenoca stomach obs 80% (in situ)	M 51	5	62.05	46.59	46.59	46.59	55	29.56	0.69	12.25	1.10	+16.22	4250	3335	9.15	36	230	179	32	33	6018	4650	2370	1810	10250	417	Total	417
C3	Adenoca stomach obs 85% (in situ)	M 7	7	70.45	48.00	48.00	48.00	50	22.00	0.60	12.65	0.62	+9.46	2680	2020	6.78	52	158	131	31	29	4320	3090	1370	1070	17470	455	Total	455
E3	Ca. rectum (in situ) removed	M 59	9	58.39	40.00	31.5	45.50	55	27.61	0.67	13.06	4.30	+10.12	3048	3110	6.52	52	191	170	33	31	4690	4350	2641	1397	13390	342	Total	342
E4	Ca. rectum (early in situ) Removed	M 59	9	69.50	60.50	48.18	50.50	55	39.03	0.83	15.87	0.91	+21.3	3005	3270	5.03	75	168	169	36	40	4150	3445	1142	1185	13970	290	Total	290
E5	Ca. rectum removed	M 40	10	69.50	67.73	2.5	72.00	50	53.76	0.78	16.42	1.97	+35.38	3910	3750	6.63	7	259	269	39	41	6310	6390	2400	2620	20650	320	Total	320
E6	Ca. rectum removed	M 40	6	81.57	46.81	42.7	52.80	55	21.84	0.68	11.89	0.80	+11.80	3034	3765	6.02	5	244	196	36	30	4770	4370	3054	3765	11710	250	Total	250

* Per kilogram of body weight

for the rectal cases preoperatively (E3 and E4), the fecal nitrogen was small in comparison with the intake nitrogen, that the nitrogen deposition ranged from 10.12 to 35.38 gm., and that the weight gains ranged from 0 (E4) to 5.69 kg. It is to be remarked that the level of nitrogen intake is from 150 to over 300 per cent that of the traditional "high protein intake." E4 is puzzling in that with a deposition of over 100 gm. of nitrogen preoperatively, no weight gain was registered. If the thiocyanate space had been determined on this patient an explanation for this stationary weight might have been supplied by a drop in the post-feeding thiocyanate space.

While these few cases are not conclusive, this study so far has shown that protein-depleted cancer patients can be hyperproteinized successfully with resulting large nitrogen balances and weight gains. There seems to be a tendency for those with the growth *in situ* to be able to ingest less than after its removal, which may explain the larger positive nitrogen balance and larger weight gains in the postremoval cases. Despite this tendency the positive balances in the patients with cancer *in situ* have been from 200 to 400 per cent of the highest retention in the usual level of hospital food regimen.

Up to this point there does not seem to be any striking differences in the nutritional behavior of cancer and noncancer cases of protein depletion to hyperproteinization. There is, however, a difference which will be brought out in Part II.

Feeding in Cases of Obstruction.—Table 3 is the nitrogen balance record of C3 who had an 85 per cent obstruction of the stomach caused by a gastric ulcer. It will be seen that the vomiting following the ingestion of cooked food disappeared entirely with the administration of protein hydrolysates. This ability of the protein hydrolysate to be tolerated in the presence of an obstruction has been encountered also in nonmalignant obstructions.^{10, 11}

It will be seen from Table 3 that the vomiting stopped immediately after the administration of the protein hydrolysates, that the nitrogen balance became positive, averaging more in the first three days, less in the next two days and still less in the last two days. The body weight rose 1.9 kg. in seven days. The SCN-S which originally was 17,470 cc. sixteen days before had fallen to 12,350 cc., (from 455 to 320 cc. per kilogram of body weight) after the hyperproteinization period, suggesting that the weight gain was not due to increased extracellular fluid.

The wisdom of hyperproteinizing patients with malignancy may be questioned in view of the possibility of the tumor itself also being stimulated into more rapid growth. This possibility may be partly counterbalanced by the possibility that malignant tissues may already be proliferating at a maximum rate and that the access of more nutriment

cannot accelerate the growth further. Neither possibility is capable of an early confirmation, and until that is done the surgeon must balance between the danger of operating on a poor surgical risk on the one hand and the danger of accelerating the development of the growth on the other.

II. THE BLOOD CONSTITUENTS AND FLUID COMPARTMENTS

The blood constituents and fluid compartments investigated were:

- The total plasma volume (PV)
- The plasma protein level (PP)
- The hematocrit (Hmt) and
- The total thiocyanate space (SCN-S)

From the first three primary values are computed six derivative values:

- The total blood volume (BV)
- The per kilogram (relative) plasma volume (PV/W)
- The per kilogram (relative) blood volume (BV/W)
- The total circulating plasma proteins (TPP)
- The per kilogram total circulating plasma proteins (TPP/W)
- The total red cell mass (RCM)
- The per kilogram body weight (relative) red cell mass (RCM/W)

From the last primary value, the total SCN-S is calculated:

- The per kilogram thiocyanate space (SCN-S/W)

Table 4 summarizes the finding in twenty-six cases, sixteen of which were included in the eighteen cases in Table 1. In this present work single total values for PV, BV, the SCN-S, RCM and TPP were used mainly as steps from which to derive the corresponding per kilogram values. These latter are more significant than the total values since the latter by themselves without the corresponding premorbidity values for comparison are valueless. To derive the theoretical premorbidity total values from the history of normal weight or of weight loss is hazardous in civilian practice, unless it can be confirmed by other means. To determine these premorbidity total values from age and height tables is equally unreliable since the minimum and maximum weights may vary as much as 34 per cent. Where serial determinations can be performed in the evolution of the picture of depletion and repletion as were done in the hyperproteinization work in Tables 2 and 4, the total values are useful. In the present paper more attention will be given to the per kilogram than to the total values.

TABLE 4
SUMMARY OF FINDINGS IN TWENTY-SIX CASES

	Case No.	PV (cc)	PV/W (cc)	PP (gm per 100 cc)	TPP (gm)	TPP/W (gm)	Hmt	BV	BV/W	RCM	RCM/W	SCN-S	SCN-S/W	Per Cent Weight Loss
Mouth Parts	A1	2708	57	6.25	169	3.54	44	4835	102	2127	44.6	18520	388	36.0
	A2	2697	59	6.70	175	3.90	35	4011	91	1404	31.6	17275	388	—
	A3	3490	64	7.10	247	4.50	40	5818	107	2327	42.8	19390	357	23.2
Esophageal	B1	2680	57	6.65	178	3.70	35	4125	87	1440	30.5	20650	440	35.0
	B2	2909	54	7.30	212	4.00	40	4848	90	1939	35.8	18520	316	35.0
	B3	2524	53	4.86	123	2.70	33	3707	78	1243	25.9	13335	280	38.0
	B4	2783	61	6.50	181	4.10	44	4970	114	2186	50.1	—	—	—
Gastric	C1	2548	65	5.27	134	3.50	26	3443	88	895	22.8	15835	404	42.0
	C2	4250	92	5.41	230	5.00	32	6120	143	2370	51.4	19230	417	35.0
	C3	2980	78	5.32	158	4.13	31	4320	110	1340	33.1	17470	455	35.4
	C5	3150	55	5.37	169	2.97	38	5480	89	1930	34.0	—	—	25.0
	C6	3114	68	6.24	194	4.25	38	5025	110	1910	41.8	18630	403	27.2
	C7	3060	58	5.64	173	3.30	29	4310	82	1250	23.8	20835	397	30.0
	C8	3410	68	5.23	178	3.60	34	5170	103	1758	35.2	—	—	—
	C9	4957	70	5.48	239	4.15	27	5970	104	1612	28.0	23260	404	—
	C10	2888	56	6.36	184	3.49	38	4658	88	1770	31.7	—	—	—

Colon	D1	2500	42	6.12	153	2.54	40	4165	69	1666	27.7	14410	238	14.0
	D2	2495	57	7.01	175	4.01	35	3840	88	1340	30.8	16380	376	26.0
	D3	3035	63	6.02	244	3.91	36	4770	102	1720	36.7	11710	254	31.4
Rectal	E1	4225	60	6.75	285	4.04	30	6036	86	1780	24.2	—	—	11.3
	E2	2580	52	5.46	133	2.66	37	4100	82	1516	30.5	10806	216	—
	E3	3050	76	5.92	191	4.75	35	4690	117	1640	41.0	13890	342	31.5
	E4	4080	59	6.43	262	3.77	39	6790	96	2610	37.6	—	—	000
	E5	2750	47	5.94	163	2.80	45	4995	86	2250	38.6	16130	277	19.8
Extragastric- total	F1	3560	66	7.44	265	4.90	35	5496	103	1934	36.5	17544	327	15.5
	F2	3280	51	6.14	201	3.14	35	5048	80	1707	25.6	19230	300	12.7

Some reference has been made in Part I to the Minnesota Project under the directorship of Ancel Keys,² where the changes undergone by thirty-two volunteers were carefully followed from the beginning to the end of twenty-four weeks of semistarvation. This monumental work will go down in medical history as an extension and amplification of the work of Benedict.² It is so basic that it will serve as a point of reference for future work having to do with protein depletion. In our present work it will be freely drawn upon in the appraisal of our own findings.

The Per Kilogram (Relative) Plasma Volume (PV/W).—The PV/W is derived from the present plasma volume as determined by the method of Gregersen¹² and the present weight. If the normal range is from 40 to 55 cc., it will be seen from Table 2 that of the twenty-six values none were below this range, seven were within this range while nineteen were well above, the highest being C2 with a value of 95 cc., which is a value high even for the standard per kilogram blood volume. Figure 163 is a graphic representation of these individual twenty-six values and of the averages from each group. It will be seen that in all the groups the average values were well above the normal ranges. This hyperplasmovolemia signifies a tendency to fluid plethora or hydremia of the blood, and has been reported in starvation cases at Belsen by Mollison,¹³ in Japanese-held Indian prisoners of war by Walters et al.,¹⁴ in cases of protein depletion at the termination of nonmalignant diseases¹⁰ and in the Minnesota Project² where in twelve weeks of starvation, the PV dropped from an initial of 3257 to 3206, the PV/W from 48.2 to 54.2; in twenty-four weeks the PV was 3541 and the PV/W 64 cc.

The Plasma Protein Level (PP).—In addition to the twenty-six values given in Table 2, twenty-two other values with hematocrit are available from previous work on cancer cases. If the range between 6.25 and 7.5 gm. per 100 cc. is taken as normal, between 6 and 6.25 as borderline and below 6 as definitely low, it will be seen from both Table 2 and Figure 164 that, except for the oral and the extragastrointestinal groups in which the values were above the lower limits of normal, in all the other four groups there were scattered, normal, borderline and definitely low values. The most consistently low values, however, were found in the gastric group. The average of the rectal group was the next lowest which was, however, well within the normal range.

The Per Kilogram Total Circulating Plasma Proteins (TPP/W).—This value is derived from the PV and the PP. The theoretical normal value computed from a standard PV/W of 45 cc. and a PP of 7 gm. per kilogram would be 3.15 gm. In Walters' series¹⁴ of nine normal Indian soldiers, the value was 3.33 ± 0.3 . The normal range may therefore be set between 3.15 and 3.6 gm. per kilogram. In our series of twenty-six

cases, four cases fell below the normal ranges as set here (B3, C5, D1 and E2), seven were within the range and fifteen were above.

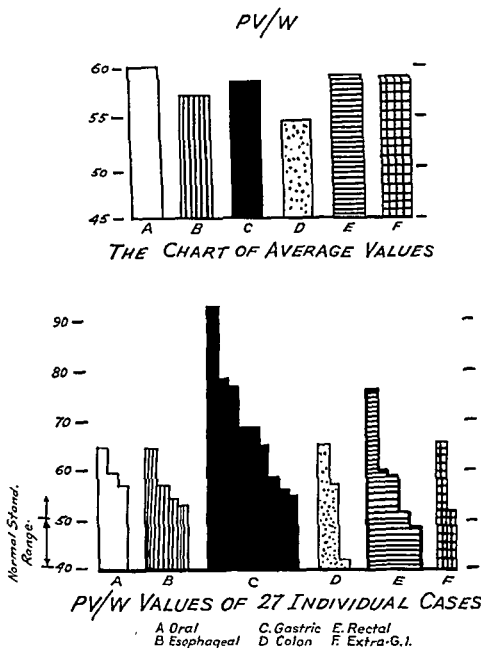


Fig. 163.

This sustention of the plasma protein level and the total circulating protein is well exemplified in the Minnesota cases. After twelve weeks of semistarvation, the body weight had dropped 18.7 per cent; but the plasma protein level had changed from 6.85 to 6.55 gm. per 100 cc.;

the TPP from 223 to 217 gm. The albumin which according to traditional concepts should have dropped had instead risen from 4.34 to 4.59 gm. per 100 cc., with a rise in total circulating value of from 133 to 147 gm.

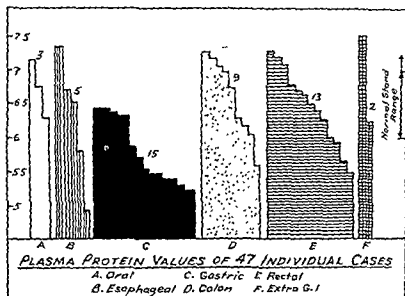
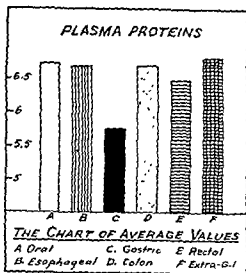


Fig. 164

In twenty-four weeks, when the weight had dropped 24 per cent, the plasma protein level had been reduced to 6.12 gm. per 100 cc. with a TPP still 210 gm., and the albumin values were 3.92 gm. per 100 cc. with the total circulating value still 193 gm. This tendency of the total

circulating plasma proteins to be sustained and the TPP/W to rise despite the loss of weight in protein depletion signifies three points: (1) the presence of a homeostatic mechanism defending the oncotic pressure of the blood during the development of hyperplasmovolemia; (2) that the operation of the law of dynamic equilibrium of body constituents postulated by Whipple¹⁶ and extended by Schoenheimer¹⁷ may be subjected to modification by homeostatic factors; and³ the level of the total circulating blood proteins (even of albumin) and the TPP/W are not reliable yardsticks for the degree of protein depletion.

The Hematocrit (Hmt).—The forty-seven hematocrit values and the averages of the six groups are graphically shown in Figure 165. The lowest values were found in the gastric group, where the one highest value is just at the lower limit of normal and the average is the lowest of all groups. It is interesting that the averages for the colon and the rectal groups are within the normal range.

In the Minnesota series the hematocrit dropped from 46.4 to 39.8 and 36.6 at the end of twelve and twenty-four weeks of semistarvation.

The Total Blood Volume (BV).—This value is derived from the PV and the hematocrit and is therefore affected both by hydremia and the degree of anemia. In the Minnesota series, the BV fell as the body weight fell in the first twelve weeks but less in proportion to the weight. In twenty-four weeks it was found to be rising. This rise is again attributable to increasing fluid plethora. Lyons¹⁸ called this fall from the pre-morbidity level, chronic shock. In our own series the BV was of no value for comparison with the previous status and as stated above was useful only as a step for the determination of the BV/W.

The Per Kilogram (Relative) Blood Volume (BV/W).—If from 80 to 90 cc. per kilogram is set as normal ranges, it will be seen from both Table 2 and Figure 166 that only two values and these in the B and D groups fell below this range; twelve values were within the normal while thirteen were well above normal. Among the averages, the gastric group had the highest. In Keys' group as starvation progressed, the PV/W rose from an initial of 83 cc. to 90.3 cc. in twelve weeks and 100.8 cc. in twenty-four weeks. This rise also constitutes another sign of hydremia in protein depletion.

The Total Red Cell Mass (RCM).—This is computed from the hematocrit and the plasma volume. In the work of Keys the fall in this element is the most consistent, being 21.8 per cent and 25 per cent respectively in twelve and twenty-four weeks of semistarvation. This is more consistent than the loss of weight. Apparently the storage of fluids which throws the other values out of line does not apply to the RCM. In our series, unfortunately, we have no initial values.

With regard to the RCM/W, the figures for normal as derived from

the standards of BV of 85 cc. and PV of 45 cc. would be 40 cc. per kilogram. In Keys' series the normal was 3.8, dropping to 3.7 in twelve weeks and climbing back to 3.8 in twenty-four weeks. In our series in

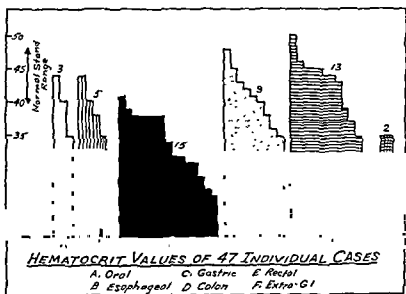
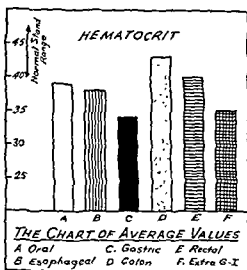


Fig. 165.

Table 2, the values ranged from a low of 25.6 to a high of 51.4. It appears that this entity is valueless as a factor of appraisal of the protein state.

The Total and Relative Sodium Thiocyanate Space (SCN-S and SCN-S/W).—The SCN-S in this work was determined by the method

of Laviates.¹⁸ This value has been assumed to represent the extracellular fluid, which seems to be the case in the normal individual.

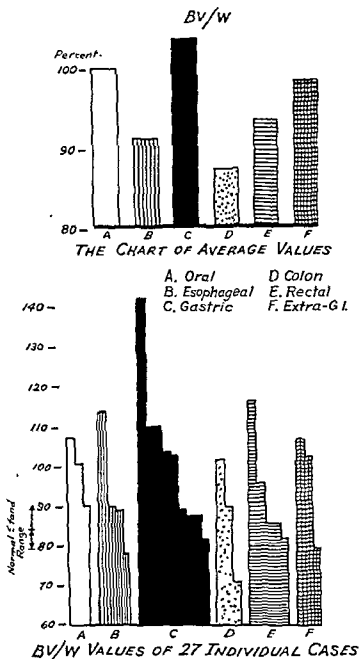


Fig. 166.

The elevation of this value in protein depletion has been shown by Lyons¹⁵ in war-wounded and by Henschel et al.¹⁹ in semistarvation, and our work in noncancerous patients. Henschel found a rise in normal subject to 340 cc. per kilogram of body weight after twenty-four weeks of semistarvation.¹⁹ In our present series, the SCN-S/W values are

represented numerically in Table 4 and graphically in Figure 167. It will be seen from both the figure and the table that in the twenty cases in which this test was performed under basal conditions, there were only

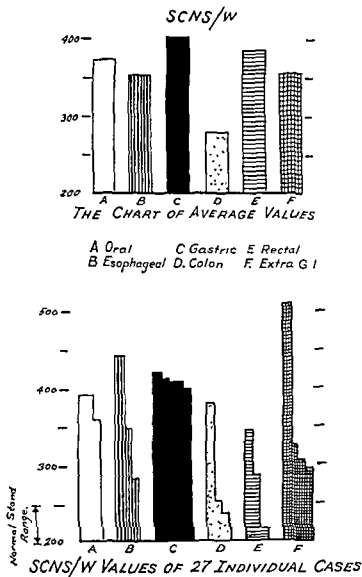


Fig 167.

two values within the range of normal. All the others are significantly above normal.

The question arises whether the SCN-S does in actuality represent the extracellular fluid in protein depletion. Because of some recent work showing that in some pathological conditions it may approach the value

of total body water,²⁰ it is now accepted that some other factors, perhaps that of increased tissue permeability, enters the picture to make the value higher than actual, and that therefore this value is not a faithful representation of the extracellular fluid volume. However, in Lyons' cases and in Keys' cases and in our work on protein depletion both in noncancerous and cancerous patients, there seems to be a consistency in the rise of this value with the intensity of protein depletion. Therefore, with the full knowledge that this value is not a good measure of the extracellular space, it is nevertheless retained as another one of the indices of protein depletion, none of them precise but the integration of all giving an approximate picture of its severity.

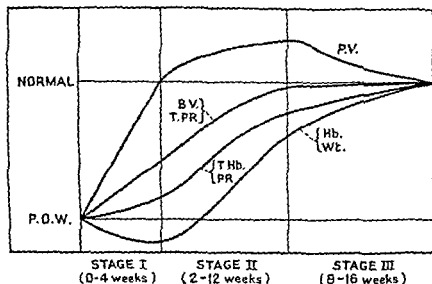
The significance of the rise in the PV/W, the BV/W and the SCN-S/W may now be examined. All the three findings point to overhydration of the blood and perhaps of the tissues. These findings and the fact that protein-depleted patients are prone to edema may lead to the conclusion that overhydration is the rule in protein depletion. However, it has also been known that the development of this type of edema is not a constant feature. Denz²¹ has shown that when these depleted patients are put at bed rest, there is a marked diuresis, a marked fall in body weight and a falling of the BV/W and PV/W to below normal values. Therefore it appears that the fluid content of the blood and perhaps of the tissues, rather than being consistently increased or decreased, has a much wider latitude of fluctuation than in the normal person. For this reason abnormally high and abnormally low values may be expected and is perhaps a more sensitive index of depletion than a fall in the plasma protein, in the albumin level or in the hematocrit. These last three values may be valuable when present, but in borderline cases they may be misleading.

In this connection it will be interesting to report some preliminary results with determination of body water²² in B1, whose premorbidity weight was found to be 73.9 kg. If the total body solids lay between 30 and 42 per cent, his total body solids at that time should have been 22.17 to 29.56 kg. His present weight was 47.3 kg., representing a loss of 36 per cent. His total body water determined by the use of deuterium oxide was 31.1 liters. This subtracted from his present body weight leaves a figure of 16.2 kg. for present body solids, representing a loss of some 36 to 48 per cent of his total body solids, the former figure checking closely with the calculated weight loss.

Throughout this study, the gastric group seems to show more signs of protein depletion than the other groups by a number of criteria: the elevation of PV/W and of BV/W, the low PP level, the low hematocrit and the rise in SCN-S/W. Whether this indicates that in gastric cancer

protein depletion tends to be more severe than in other types requires more study.

Changes in Blood Constituents and Fluid Volumes in Cancer Patients During Hyperproteinization.—In the foregoing section, the statement was made that, although the nutritive response to hyperproteinization in cancer patients was similar to that of noncancerous patients, there were features which were different. The difference arises in changes in blood volume, plasma volume, total plasma proteins and red cell mass. In the depleted patient without existing disease, the response to hyperproteinization is of a large increase in plasma volume, a slight lag in plasma protein formation for the first week to be followed by a significant



rise, specially in the albumin fraction; and a lag in the RCM for the first two weeks, followed also by a steady rise. This lag in the plasma protein and red cell formation has been explained on the basis that since they are proteins having to be manufactured by other tissues which are themselves depleted, repletion of these tissues has to progress to a certain point before the manufacture of these two proteins can take place. Using the initial values as a basis and expressing the subsequent values as percentage rises over the initial, the curves of these values may be represented as in Figure 168 which has been adapted from Walters.¹⁴ Since Walters' determinations were spaced further apart than ours, the initial lag in the TPP and the RCM would be missed in these curves.

In our cases of cancer in the gastrointestinal tract before removal, except on B1, the response is a large initial fall of all these elements: PV, BV, RCM, and TPP. This fall may be seen in the second part of Table 2 in C2, C3, E3 (first period) and E4 (first period). The failure of TPP to rise has been observed by Homburger in cases of cancer of the stomach and has been attributed to some dysfunction of the liver.²³ The same negative response is also observed in active pulmonary tuberculosis,²⁴ for which no explanation is available at present. This larger decline in the RCM and TPP constitutes added indication for blood transfusions in the preoperative preparation for surgery as recommended by Lyons et al.¹⁵ In the postremoval cases, E4 (second period), K3 and D5 (second period), the positive trend of the values is again in evidence. The negative trend of these values before removal and the positive trend after removal, which is more marked in the case of RCM than of TPP, is striking in E3 and E4, both of whom served as their own controls.

SUMMARY AND CONCLUSIONS

In a two-fold study of cancer patients, it was shown:

1. That the voluntary intake of hospital prepared food cannot usually keep a cancer patient in nitrogen equilibrium.
2. That the forcing of hospital prepared food to cancer patients may achieve nitrogen equilibrium in some cases but the response is capricious.
3. That by the use of protein products specially prepared for rapid absorption, large positive nitrogen balances can be achieved even with the growth *in situ*.
4. That such a hyperproteinizing regimen in order to be successful must take into account special precautions peculiar to this type of feeding.
5. That the nitrogen excretion in the urine of cancer patients with protein depletion is greatly reduced below normal, showing no appreciative protein destruction and the operation of a conserving mechanism as in noncancerous patients.
6. That although the nutritive response of cancer patients with protein depletion is similar to that in noncancerous patients, the fluid compartments and blood constituents react differently, resulting in a fall of the total plasma volume, total blood volume, total red cell mass and total circulating plasma proteins.
7. That this negative feature indicates the use of both hyperproteinization and transfusions in the preoperative preparation of cancer patients.

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LABORATORY DIAGNOSIS AS AN AID TO SURGERY

B. H. KEAN, M.D.*

ALTHOUGH the clinical pathologist can offer considerable assistance to his surgical colleague in the differential diagnosis of disease, in guiding therapy and in evaluating prognosis, the limitations of laboratory procedures must be fully appreciated if errors in the handling of the patient are to be avoided. Too often it has been my unhappy experience to learn that the decision as to whether or not an appendectomy should be performed turned upon the leukocyte count or erythrocyte sedimentation rate. A patient may have a gangrenous appendix with a normal white count whereas a leukocytosis caused by an unrelated factor may be responsible for the mistaken diagnosis of appendicitis.

Because of the multiplicity of laboratory procedures which are available, the surgeon is often forced to choose from several which purport to provide the same information. As a matter of principle it is best to pick the simplest procedure, the one which has had the longest period of testing and, for the benefit of both the patient and the institution, the cheapest. It is obvious that when a dozen tests are available for the same condition, none is worth much. If several tests are desired, two or more which are based upon different principles should be chosen. For example, in the differential diagnosis of liver disease it is foolish to request a cephalin flocculation test, a thymol turbidity test and a Takata-Ara test since all three are expressions of the presence of abnormal proteins in the serum. More useful data can be obtained by a simple study of the urine, one test for abnormal serum protein, and an estimation of serum phosphatase.

Not infrequently, and regardless of how carefully the work may be performed, a laboratory result may be at complete variance with the clinical findings and with the other laboratory studies. Under such circumstances one can only disregard the uncooperative report.

No one is more cognizant of the limitations of laboratory data than those who provide them. The more experienced the surgeon, the less will he be dependent upon laboratory assistance.

In this paper I shall discuss those tests which are most useful to the surgeon and will emphasize the simpler techniques which can be performed in most laboratories. The procedures are described in detail in most texts on clinical pathology. A consideration of surgical bacteriology has been omitted deliberately.

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HEMATOLOGY

Complete Blood Count.—The usefulness of a complete blood count hardly need be emphasized at this time but, sadly enough, many minor surgical procedures and not too rarely a major operation is undertaken without a hemoglobin, erythrocyte and leukocyte determination.

Hemoglobin should be reported in grams per 100 cc. and not in percentage, since the latter varies depending upon standards. The normal hemoglobin for males is 14.5 to 17 gm. per 100 cc. and for females 13 to 16 gm. An acid hematin method such as the Sahli is preferred if more exact methods are not used. The Tallqvist technic is about as accurate as a visual examination of the tongue.

Normally, men have 5,000,000 *erythrocytes* and women 4,500,000 per cu. mm. of blood, but the state of hydration of the patient and inaccurate counts may easily mislead the unwary. Several rather cumbersome formulas have been developed by hematologists to help in the classification of the anemias but the surgeon rarely finds them useful and still relies on the old classification of primary anemia (generally hyperchromic macrocytic) and secondary anemia (generally hypochromic microcytic). Bleeding from the intestinal tract and malignant disease are the two commonest causes of severe anemia with which the surgeon is confronted.

Basophilic stippling of the erythrocytes which can be recognized on routine stained smears may provide the clue to lead poisoning which may be responsible for such severe abdominal pain that an acute abdominal emergency is suspected.

The *leukocyte* count is most useful in determining the presence of infection but too much dependence should not be placed upon it. The differential count may offer more useful data than the total count if the "shift to the left" is marked. Smears will also explain cervical lymphadenopathy caused by infectious mononucleosis, or an eosinophilia may direct attention to parasites responsible for gastrointestinal symptoms. Since the sulfonamide preparations have been used so widely, unexpected leukopenia or even agranulocytosis may have been produced by the physician or even by the patient without knowledge of the physician.

It should be remembered that regardless of infection a *postoperative leukocytosis is usual*.

The *parasites* of the blood which warrant attention are those causing malaria and filariasis. An exacerbation of malaria not infrequently follows an operation, especially an orthopedic procedure, and may unless the cause is recognized lead the surgeon to the mistaken conclusion that infection has occurred. Parasites may not be found unless a *thick film* is examined by an experienced technician.

Filariasis may cause *erysipelas-like lesions of the extremities*, elephantiasis, hydrocele or inguinal lymphadenopathy. It will be encountered in

natives of Puerto Rico and the South Pacific islands, but is not to be anticipated in veterans who served in those islands. A thick film taken at midnight may provide the diagnosis. Removal of a lymph node for diagnostic purposes may precipitate an attack with exaggeration of the elephantiasis.

Erythrocyte Sedimentation Rate.—The flurry about this test is over. The rate of settling of the formed elements of the blood is an expression of the status of the plasma proteins and is increased in patients with acute inflammation, cancer, tuberculosis and many other diseases. Its greatest usefulness has been found to be not in differential diagnosis but in following the course of the patient or in distinguishing psychosomatic complaints from those caused by organic disease; the "psychoneurotic" with an elevated sedimentation rate deserves careful re-study. The simple Westergren technic is preferred. The normals are 15 mm. in one hour for men and 20 mm. for women. In pregnancy the rate is normally high after the fourth month. Anemia increases the rate.

Tests for Abnormal Bleeding Tendency.—Until a few years ago the surgeon's interest in the bleeding tendency of his patient was almost academic since there was little that could be done in the way of accurate diagnosis, prevention and treatment. Now, with the discovery of vitamin K, the use of heparin and dicumarol as anticoagulants and the availability of blood for transfusion, many careful surgeons are requesting, as routine preoperative procedures, a platelet count, a determination of capillary bleeding and coagulation time, clot retraction time and prothrombin time. The tourniquet test is most useful for the clinical estimation of capillary frigidity. Except for the prothrombin time these studies require little material and can be done by almost any technician.

Several technics for the determination of the prothrombin time have been published but the methods of Quick are most widely used. It is important to use the same lot of thromboplastin for tests on the same patient since different lots have different potencies. Platelets range normally from 200,000 to 500,000 per cu. mm. In purpura haemorrhagica (thrombocytopenic purpura) platelets are reduced in number. Coagulation time in this disease is normal but clot retraction is delayed. The patient with hemophilia shows a marked increase in the coagulation time of his blood because of the congenital abnormality of his platelets (increased resistance) but the bleeding time, prothrombin time, clot retractility and capillary fragility are normal.

Hematocrit.—This simple test is an excellent index of the state of hydration of the patient and is extremely useful in guiding intravenous therapy of patients with burns. If blood is placed in a tube such as that devised by Sanford and Magath or Wintrobe or Haden and centrifuged until packing is complete, the ratio between the formed and liquid ele-

ments of the blood can be obtained. Normally, 40 to 46 per cent of the blood is composed of formed elements. In dehydration the hematocrit value may rise to 60 per cent or more; if excess fluids have been administered it may drop to 25 per cent.

In shock the hematocrit rises and so the surgeon can distinguish between that condition and hemorrhage in which the hematocrit falls

Fragility of Erythrocytes.—In congenital hemolytic icterus the erythrocytes are smaller than normal, spherical rather than biconcaved disks, and disintegrate in saline of various concentrations more readily than normal red blood corpuscles. Removal of the enlarged spleen is curative in most cases.

Sickleemia.—In Negro patients the sickle cell trait may be associated with ulcers of the legs, attacks of abdominal pain possibly due to minute thrombi, or severe anemia. In addition, it has been suggested that the anoxia produced during the induction of a general anesthesia may cause sickling of the erythrocytes and result in an anesthetic casualty.

Blood Grouping Including Rh Factors.—This subject is now so large and of such importance that it should not be included as part of a general survey

Bone Marrow.—Aspiration of the bone marrow either from the sternum or iliac crest may establish the diagnosis of malignant disease, explain bone destruction by multiple myeloma, or solve the riddle of splenomegaly caused by leukemia, Gaucher's disease or thrombocytopenic purpura. It is a technic to be used in consultation with the hematologist

CLINICAL CHEMISTRY

Blood specimens should be obtained after the patient has fasted for ten to twelve hours, although only the blood sugar determination will show significant clinical variation at different times in the day.

Sugar.—The dangers of operating upon a patient with unrecognized diabetes need not be discussed. Ordinarily the determination of blood sugar will not be done unless sugar is found on routine urine analysis. An elevated blood sugar, and by this is meant a figure above 130 mg. per 100 cc. (fasting), with or without the presence of glycosuria, should be an indication *not* for the diagnosis of diabetes mellitus, but for the performance of a sugar tolerance test. The Rose-Exton test requires fewer venipunctures than the standard determination and probably provides as much information. However, we are still prejudiced in favor of the standard test, which permits the graphing of results in a little more dramatic fashion. The presence on repeated examination of a low blood sugar value (below 75 mg.) suggests, of course, a tumor of the islets

of Langerhans, although other conditions may be responsible. Since spontaneous glycogenesis occurs at the rate of about 5 mg. per hour in vitro, the sugar determination must be made with a freshly drawn specimen.

Azotemia.—Evidence of renal insufficiency, if severe, may be obtained simply by the determination of the nonprotein nitrogen or urea nitrogen of the blood. The nonprotein nitrogen is the more popular, but the test for urea nitrogen can be done much more easily and just as useful information be derived. The normal nonprotein nitrogen is listed as 25 to 35 mg. per 100 cc., and the urea nitrogen 10 to 15 mg. Broadly speaking, if the urea nitrogen is doubled, the figure will be approximately that of the nonprotein nitrogen. The creatinine determination provides no additional information in most instances.

In prostatic disease a test for azotemia should be routine.

Serum Proteins.—The normal serum albumin is 3.5 to 5.5 gm. and the globulin 1.5 to 3.5 gm. per 100 cc. If the serum proteins are reduced, delayed wound healing, difficulty in maintaining proper fluid balance and congestive heart failure are surgical complications to be feared. Hyperproteinemia may be due to dehydration (temporary), burns, Addison's disease, multiple myeloma and parasitic diseases. Hypoproteinemia may follow malnutrition, liver disease, especially cirrhosis with ascites, albuminuria and prolonged vomiting.

Uric Acid.—Gout may easily be confused with thrombophlebitis or acute arthritis, especially since an attack of gout frequently follows any surgical operation on those afflicted with the disease. A blood uric acid over 5 (normal 2 to 4) mg. per 100 cc. will be helpful in the differential diagnosis, but occasionally gout may be present with a normal blood uric acid. Tophi of the ears or other areas may be confused with soft tissue tumors.

Cholesterol.—Cholesterol values generally are high (normally 140 to 250 mg. per 100 cc.) in cholelithiasis, uncomplicated biliary obstruction, pregnancy, diabetes mellitus and hypothyroidism. In hyperthyroidism the value is low. In the treatment of arteriosclerotic disease of the extremities this determination will be of value.

Chlorides.—It is important to realize that the determination may be done on plasma (normal: 550 to 650 mg. per 100 cc.) or on the whole blood (450 to 500 mg.) or serum (350 to 400 mg.), and that the values differ considerably, depending upon which specimen is used. Diminution of chloride levels occurs in excessive vomiting due to gastric disease or high intestinal obstruction, prolonged diarrhea, biliary fistulas, starvation and excessive sweating. There is a tendency for hypochloremia to develop following operations upon the gastrointestinal tract. Hyperchloremia occurs most often in patients with advanced kidney disease.

Sodium and Potassium (Normal values: Sodium, 300 to 350 mg. per 100 cc.; potassium, 15 to 25 mg. per 100 cc. of serum).—The serum sodium is decreased by high intestinal obstruction, severe diarrhea, biliary or pancreatic fistulas, ether anesthesia, excessive sweating, and in Addison's disease. In those conditions in which the serum sodium is low, especially in high intestinal obstruction, the serum potassium tends to be high.

Calcium (Normal value: 8.5 to 11.5 mg. per 100 cc. of serum).—Hypercalcemia occurs in neoplastic disease of bones (especially metastatic carcinoma), in hyperparathyroidism especially with *osteitis fibrosa cystica*, and for unexplained reasons in multiple myeloma.

Hypocalcemia develops in hypoparathyroidism especially following thyroid or parathyroid operations, in diarrheal diseases, nephrosis and in advanced cachexia.

Phosphorus (Normal value: 2 to 5 mg. per 100 cc. of serum).—Usually an inverse ratio between serum calcium and serum phosphorus prevails.

Hyperphosphatemia occurs in healing of fractures, following administration of vitamin D or ultraviolet irradiation, hypoparathyroidism, acute high intestinal obstruction, and acute yellow atrophy of liver.

Hypophosphatemia may be seen in patients with *osteitis fibrosa cystica*, *osteomalacia* and fatty diarrhea.

Phosphatase.—Much confusion has arisen about the usefulness of this procedure because careful distinction is not made in laboratory reports between the *acid* and the *alkaline* phosphatase.

The *acid phosphatase* is elevated in metastatic carcinoma of bone derived from prostatic tissue.

The *alkaline phosphatase* is elevated in many conditions, especially in healing of fractures, pregnancy, *osteitis fibrosa cystica*, *osteitis deformans* (Paget's disease), metastatic carcinoma of bone, osteogenic sarcoma and obstructive jaundice. It is normal in osteomyelitis, benign giant cell tumor and Ewing's sarcoma.

Iodine.—This determination can be accomplished in relatively few laboratories, but it may be of interest to record that the value is decreased in hypothyroidism and increased in hyperthyroidism and in patients with liver disease associated with jaundice.

Acid-Base Balance.—Buffers in the blood keep its pH between 7.3 and 7.5. Acidosis may develop in diabetes mellitus, following severe diarrhea, in starvation, nephritis, pregnancy with vomiting, following anesthesia, and with pancreatic fistulas. The carbon dioxide combining power of the plasma, normally 55 to 65 volumes per cent, becomes diminished in severe acidosis which should be corrected before any

surgical procedure is attempted. Vomiting may be responsible for pre-operative or postoperative alkalosis.

RESPIRATORY TRACT

Sputum.—A carefully conducted examination of the sputum is an invaluable reflection of the pathologic state of the respiratory tract. Unfortunately, adequate distinction is rarely made between *sputum* which is derived from the tracheobronchial tree, and *saliva*, which the patient is much more inclined to provide.

In the diagnosis of bronchiectasis the excessive quantity of sputum, its tendency to form layers, and its odor often provide immediate clues as to diagnosis. Too often hemoptysis is considered evidence of pulmonary tuberculosis when in reality bronchiectasis is responsible. Careful bacteriologic examination of the sputum has been thought to have lost much of its value since the advent of specific therapy. However, if the sputum is studied bacteriologically the efficacy of sulfonamide, penicillin and streptomycin therapy can be judged and the optimum time for operative intervention determined. In abscess of the lung, cultures, including anaerobic cultures, and detailed studies of smears are advised. The leukocyte count and sedimentation rate will be helpful in diagnosis and in following the course of a lung abscess.

Biopsies.—Biopsy of tumors of the larynx, trachea and bronchi remains the keystone in the differential diagnosis of these lesions. Concern lest biopsy spread the lesion is unjustified. Recently successful attempts have been made in establishing the diagnosis of respiratory tract cancer by studying the cytologic elements of the sputum and material removed by laryngoscopic or bronchoscopic aspiration without biopsy. Unquestionably in some instances the shedding of tumor cells into the tracheobronchial tree is of such a nature that a diagnosis of cancer can be made without great difficulty. To date, however, the method has not been adequately evaluated and a cautious attitude must be adopted.

Pleural Fluid.—All pleural fluid should be examined until diagnosis has been established.

Clear, light yellow fluid with a specific gravity of 1.018 or less generally contains few cells and is found most frequently in patients with cardiac decompensation.

Empyema fluid offers few diagnostic problems but smears, cultures, and animal inoculations may be required to distinguish tuberculous from pyogenic pleurisy.

Bloody pleural fluid or any pleural fluid, for that matter, most often with specific gravity over 1.018, may contain tumor cells. The fluid

should be centrifuged until a "button" of sediment is obtained and this can be treated as a bit of tissue in fixing, sectioning and staining. The inexperienced often confuse mesothelial cells with tumor cells, and a diagnosis of malignancy should rarely be made unless tumor cells in clumps are identified.

DIGESTIVE TRACT

Gastric Analysis.—Because occasionally there is difficulty in passing the tube, physicians tend to neglect the method and hence deprive themselves of much useful information.

The important problem is of course the differentiation among peptic ulcer, carcinoma of the stomach and functional disorders. Although the roentgenologist will provide the most useful information, laboratory data can be exceedingly helpful

In peptic ulcer, as a rule

1. Free hydrochloric acid is present in gastric contents and may be very high after histamine injection
2. Emptying time of stomach is often rapid, but pylorospasm may cause confusion
3. Blood may be present in great quantities. Tests for occult blood by benzidine or guaiac methods are of little use since small hemorrhages often follow passage of tube
4. Secondary anemia responds well to therapy

In gastric carcinoma, as a rule

1. Free hydrochloric acid is absent and there is no response to histamine. It must be remembered that 15 per cent of normal persons do not have free hydrochloric acid but these (except 1 per cent) show a response to histamine.
2. Much mucus is present in gastric residuum.
3. Lactic acid and the lactobacillus of Boas-Oppler may be present.
4. Tumor cells may be demonstrated in gastric washings
5. Secondary anemia responds only poorly to therapy.

Test meals, of which the Ewald is most popular, produce curves of acidity which may be of interest, but essentially the surgeon wants to know: "Is true *anacidity* present or not?", and he cares little about the curve if acid is present.

Efforts have been made to establish the diagnosis of gastric carcinoma before the patient presents himself with clinical symptoms. Routine examination of large numbers of asymptomatic patients over the age of 40 years by roentgen rays and gastric analysis has revealed tumors in so few and the procedure has been so expensive that it has not been considered practicable. The electrogastrogram of Goodman, however, is

a new technic which may revolutionize the diagnosis of diseases of the stomach. The method is simple: a stomach tube is passed and the electrical potential difference across the membrane is measured by a recording machine. The pattern in various diseases differs from that of the normal stomach. Further study is necessary before the method can be used with confidence. Incidentally, Langman has used a similar but simpler electrometric test for diagnosis of carcinoma of the cervix with promising results.

Duodenal Contents.—Only one test of the duodenal contents has any real clinical value: the microscopic examination of the centrifuged specimen for crystals of cholesterol and calcium bilirubinate and for pus. The Lyons test is lovely to behold when it works, but too often patients with no disease of the biliary tract do not produce A, B and C bile with the mathematical precision expected following the administration of magnesium sulfate. The charts listing the differential diagnosis of cholecystitis, cholelithiasis, cholangitis, cystic duct obstruction, common duct obstruction and carcinoma are pretty, but in my experience, generally useless. Even the presence of blood provides little information, since one does not know its origin. The pancreatic ferments will be discussed later.

Stool Examination.—Most stool examinations are relegated to technicians with esthetic objections to the field of coprology. If the stool is studied with the care and affection which the hematologist lavishes upon a blood film, an enormous amount of useful information will be derived. A pencil shape of the stool may, for example, suggest the rectal stricture of lymphopathia venereum or a rectal tumor. The presence of an excessive amount of mucus may indicate mucous or ulcerative colitis or, more important, the presence of a carcinoma. Streaks of fresh blood suggest hemorrhoids or a lesion low in the intestinal tract such as amebiasis or tumor. Examinations for occult blood are in disrepute because of the frequency of false positives. This is unjustified but, since the ingestion of meat may give a false positive, a positive benzidine test should not be accepted unless the patient has abstained from meat for seventy-two hours.

Parasites are responsible for intestinal symptoms much more frequently than is generally appreciated, and may be found in patients who have not lived in the tropics.

Ascariasis (roundworm disease) may simulate gallbladder disease, peptic ulcer, appendicitis, and may actually cause intestinal obstruction. The eggs are found in the stool.

Uncinariasis (hookworm disease) may cause wasting anemia, ascites suggestive of carcinoma or vague abdominal pains. The eggs are found in the stool.

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Enterobiasis (pinworm disease) is most often seen in children and causes pruritus ani; it may be associated with perianal fissures and fistulas. Not infrequently the parasite is discovered in appendices but it is questionable if it is actually responsible for appendicitis. The eggs should not be sought in the stool; diagnosis can be established by applying a 3 cm. segment of scotch tape against the mucocutaneous junction of the anus in the morning. The sticky part of the tape is then placed against a glass slide, ironed out and examined microscopically for the ova.

Giardiasis, caused by the flagellate *Giardia lamblia*, may cause epigastric discomfort suggestive of peptic ulcer, or diarrhea. The parasite can be demonstrated either in the stool or in duodenal contents.

Schistosomiasis, frequent in Puerto Ricans but also seen in veterans of the Leyte and Mindanao campaigns, may cause ulcerative colitis, polyps of the rectum and portal cirrhosis. If schistosomiasis is suspected, either the acid-ether method of deRivas or a water sedimentation method may be employed to concentrate the feces. Neither of these methods, however, approximates the usefulness of the technic developed by Ottolina. This is so simple and so valuable that a detailed description is warranted. If schistosomiasis is suspected, a proctoscope is passed and at a level 10 cm. proximal to the anus a biopsy is taken. The tissue is dropped directly into distilled water or tap water and permitted to swell into a gelatinous mass from which all of the blood is hemolyzed. This process is complete in ten to fifteen minutes, the specimen is then placed directly on a slide and a cover slip is applied. If ova are present they will be seen under low power magnification of the microscope. Active miracidia may be seen moving within the egg-shell.

Amebiasis.—About 10 per cent of the people living in the United States harbor *Endamoeba histolytica*. Of these, however, only a few ever develop symptoms of dysentery, ulcerative colitis or amebic granuloma. Nevertheless, in all patients with symptoms referable to the lower intestinal tract, amebiasis must be considered in the differential diagnosis. Even constipation may be caused by the parasite. According to some authorities, fully 50 per cent of all patients with amebiasis develop a spread of the parasite to the liver. Only in a rare individual, however, do hepatic abscesses develop. This is not a disease only of the tropics but may be found in patients who have never crossed the Mason-Dixon line. Diagnosis can only be established with certainty if the parasite is demonstrated. Complement fixation tests are only of limited value.

In the examination of the stool it is important to realize at the outset that the hunt for trophozoites and for cysts requires different methods. If the patient has dysentery, the examination of a warm stool is essential. In the absence of dysentery it is best to examine the stool passed the morning following the administration of a saline cathartic. The stool should be examined in good light, and if flecks of bloody mucus are

present, these should be fished on to a slide, warm saline added and examined under low power of the microscope. Motile trophozoites will often be found in these preparations. If this microscopic examination is negative, concentration methods *which demonstrate cysts only* should be employed. The zinc sulfate flotation method is advised; it has the additional advantage of concentrating helminthic ova. Cultures of amebae are valuable only in certain laboratories.

Confusion of *Endamoeba histolytica* with the nonpathogenic *Endameba coli* is easy. There is no eosinophilia with amebiasis.

In amebic abscess of the liver the patient most often has no intestinal complaints and many stool examinations may be necessary before the parasite is found. Pus removed by aspiration from an amebic abscess of the liver is "anchovy sauce" in appearance, bacteriologically sterile, and without characteristic odor. Trophozoites may not be demonstrated on the initial removal because they do not survive in the absence of live tissue but may become numerous on subsequent aspirations. The leukocyte count is often low in contrast to that seen in pyogenic abscess of the liver.

THE PANCREAS

Diabetes mellitus, the most important disease of the pancreas, falls within the province of the surgeon during the treatment of peripheral vascular disease, especially with gangrene, and in the treatment of pyogenic infections. Surgical procedures should be delayed until the ketosis is corrected. The carbon dioxide combining power of the blood and urine tests for acetone and diacetic acid will be helpful in this regard. The height of the blood sugar is of little consequence in preventing diabetic coma, when compared with the degree of ketosis.

The diagnosis of acute hemorrhagic pancreatitis will be aided by the presence of (1) leukocytosis; (2) increase of serum lipase; (3) high serum amylase; (4) hypocalcemia.

In chronic pancreatitis there may be (1) steatorrhea due to a deficiency of lipase; (2) lipemia; (3) creatorrhea (undigested muscle fibers in stool) due to deficiency in trypsinogen; (4) hyperglycemia due to insulin insufficiency.

In carcinoma of the head of the pancreas the findings are those of obstructive jaundice.

Incidentally, there is an elevation of serum amylase in mumps.

DISEASES OF THE LIVER

The metabolism of the liver is so complicated and the tests available for its study are so numerous and confusing that, with justification, the surgeon often prefers to depend on his clinical judgement in the differen-

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not advocate it as a substitute. The interest of the public in this technic may discredit the entire field of oncology if proper caution in emphasizing its limitations is not observed.

The weal of the patient is best served if the surgeon (1) provides the pathologist with as much tissue as possible (preferably the entire lesion with some surrounding normal tissue), (2) uses a knife instead of the cautery, (3) includes the base of the polyps, (4) avoids removing inguinal lymph nodes, (5) handles the specimen gently, and (6) discusses problem cases with the pathologist.

VALUE OF THE SECRETIN TEST IN SURGERY

HENRY DOUBILET, M.D., F.A.C.S.*

THE work of Hammersten and his group in Sweden¹ and of Greengard and Ivy² in this country resulted in the production of secretin preparations sufficiently purified for clinical use. This material, when injected intravenously under standardized conditions, can be used to measure the capacity of the pancreas to secrete pancreatic juice.^{3,10} The results of this test in a group of surgical patients suffering from diseases of the biliary tract and pancreas are presented to demonstrate that the secretin test is of value for the following purposes: (1) diagnosis of chronic pancreatitis; (2) the progress of chronic pancreatitis and the effect of operative procedures; (3) differentiation, in patients with obstructive jaundice, between carcinoma of the head of the pancreas and carcinoma involving the supraduodenal part of the biliary tract; (4) the presence of a common passageway between the bile and pancreatic ducts; and (5) the functional status of the gallbladder.

MATERIAL AND METHODS

One hundred twenty-two tests involving the use of secretin were carried out on eighty patients. The secretin test for pancreatic function was performed on sixty-five patients as a diagnostic measure. Four patients had repeated secretin tests to follow pancreatic function after section of the sphincter of Oddi. In thirty patients, a T-tube was implanted in the common duct at operation. Subsequently secretin was injected and T-tube bile was examined for pancreatic enzyme (amylase). The detection of amylase in this bile was evidence of a common biliary-pancreatic passageway.

The technic of the secretin test as established by Lagerlof was followed in principle. The use of the double lumen tube he described was abandoned. A single lumen Rehfuess tube was found satisfactory if the stomach were first washed out and the patient instructed not to swallow saliva. It was found that, with the patient sitting erect in a chair during the test, secretion produced by the stomach would not pass into the duodenum.

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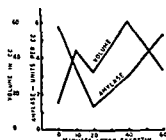
impairment than the volume of juice. It was evident that a high serum amylase occurred during an acute attack only in patients whose pancreas retained a considerable amount of functioning tissue. In general, the

TABLE 1
SECRETIN RESPONSE IN PATIENTS WITHOUT EVIDENT PANCREATIC DISEASE

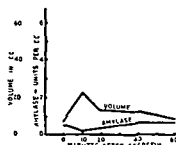
Case No.	Total Volume (Cc)	Total Bicarbonate (Cc N/10)	Total Amylase (Lagerlof Units)	Remarks
1	195	79	767	Normal gallbladder and gastrointestinal x-rays
2	216	162	776	Mucocoele of appendix
3	240	86	363	Doubtful duodenal ulcer
4	289	301	581	Biliary dyskinesia
5	214	102	1562	No pathological findings
6	380	347	1164	Third degree burn of feet
7	297	228	458	Duodenal ulcer
8	281	139	257	Duodenal ulcer
9	356	293	1166	Duodenal ulcer
10	205	97	1126	Duodenal ulcer
11	293	70	804	Biliary dyskinesia
12	195	125	453	Biliary dyskinesia
13	210	143	465	Biliary dyskinesia

TYPICAL SECRETIN TESTS

17 MG. SECRETIN (LILLY) INJECTED
INTRAVENOUSLY



NORMAL RESPONSE
TOTAL VOLUME 172 CC.
TOTAL AMYLASE 464 UNITS



ADVANCED PANCREATITIS
TOTAL VOLUME 55 CC.
TOTAL AMYLASE 14 UNITS

Fig. 169.

lowest figures for volume, bicarbonate and amylase, were obtained in patients whose pancreas, when inspected at operation, showed not only residual edema and swelling, but also considerable fibrosis.

The group of patients with obvious fibrosis, and occasionally calcification of the pancreas, gave a poor response to the secretin test (Table 4). The total volume of pancreatic juice was markedly diminished. The

TABLE 2
SECRETIN RESPONSE IN PATIENTS WITH CHRONIC CHOLECYSTITIS

Case No	Total Volume (Cc)	Total Bicarbonate (Cc N/10)	Total Amylase (Lagerlof Units)
14	159	80	347
15	180	156	467
16	142	66	241
17	76	43	181
18	130	77	816
19	105	91	418
20	275	245	794
21	181	150	474
22	156	90	395

TABLE 3
SECRETIN RESPONSE IN PATIENTS FOLLOWING ATTACK OF ACUTE PANCREATITIS WITH HIGH SERUM AMYLASE

Case No	Total Volume (Cc)	Total Bicarbonate (Cc N/10)	Total Amylase (Lagerlof Units)	Remarks
23	185	132	367	Mild edema of pancreas
24	90	43	295	Edematous swollen pancreas
25	94	39	112	Test performed during asymptomatic recurrence, serum amylase 385 mg per 100 cc
26	91	2	92	Biopsy showed marked fibrosis of pancreas
27	271	218	638	Edematous swollen pancreas
28	129	33	477	Edematous swollen pancreas
29	70	54	235	Edematous fibrotic pancreas
30	129	33	477	Enlargement of head of pancreas
31	317	116	338	No operation
32	188	102	359	Traumatic pancreatitis
33	187	116	336	Edematous swollen pancreas
34	152	115	153	No operation
35	132	34	195	Edematous swollen pancreas

bicarbonate content showed the greatest fall. Although the total amylase was very low, occasionally high concentrations of amylase would be found in a small volume of juice containing very little bicarbonate.

The patients who, in spite of severe symptoms and loss of weight, did not show a high serum amylase even during acute attacks, and whose

TABLE 4

SECRETIN RESPONSE IN PATIENTS WITH CHRONIC PANCREATITIS WITH NORMAL AMYLASE DURING PERIOD OF OBSERVATION

Case No	Total Volume (Cc.)	Total Bicarbonate Cc N/10)	Total Amylase (Lagerlof Units)	Remarks
36	126	—	340	Mild fibrosis
37	105	—	297	Calcification of pancreas
38	110	35	568	Generalized fibrosis of pancreas
39	55	3	14	Calcification of pancreas
40	182	46	110	Irregular fibrosis of whole pancreas
41	42	12	43	Generalized fibrosis of pancreas
42	35	7	23	Calcification of pancreas
43	120	14	65	Calcification of pancreas
44	40	2	88	Widespread fibrosis of pancreas
45	58	—	25	Enlarged fibrosed head of pancreas (biopsy)
46	230	65	737	Irregular fibrosis of head of pancreas

TABLE 5

SECRETIN RESPONSE IN PATIENTS WITH PANCREATITIS DIAGNOSED BY EXCLUSION (SEVERE SYMPTOMS, SERUM AMYLASE NORMAL, PANCREAS NORMAL TO PALPATION)

Case No.	Total Volume (Cc.)	Total Bicarbonate (Cc N/10)	Total Amylase (Lagerlof Units)	Demonstration of Common Passageway
47	172	153	567	+
48	121	72	370	+
49	101	95	247	0
50	141	71	193	+
51	187	85	215	+
52	143	99	497	+
53	141	82	584	Not attempted
54	62	19	150	
55	66	20	325	+
56	60	—	62	0
57	88	14	272	+

pancreas was found to be normal on inspection at operation, usually gave a diminished response to the secretin test (Table 5). The cause of this apparently functional impairment of the pancreas, somewhat similar to

the findings in chronic cholecystitis, could not be explained except as a result of the increased back pressure on the gland. The underlying difficulty in these patients was spasm of the sphincter of Oddi, since section of the sphincter relieved most of these patients of their symptoms. The secretin test was of considerable value in some of these cases, since it was of help in making the decision to operate on a patient who had no obvious pathology by any other test.

In four patients who were treated for pancreatitis by section of the sphincter of Oddi, the secretin test was repeated at a later date (Table 6). In Case 27, the pancreas was found edematous and swollen three weeks after an acute attack. Although the operation prevented later attacks, it is obvious from the diminished secretin test that the previous attacks resulted in fibrosis which led to mild impairment of pancreatic function.

TABLE 6
EFFECT OF SPHINCTEROTOMY ON SECRETIN TEST

Case No	Total Volume (Cc)	Total Bicarbonate (Cc N/10)	Total Amylase (Lagerlof Units)	Months after Operation
27	271	218	638	Preoperative
	165	81	168	8
30	90	—	90	Preoperative
	200	179	121	12
36	126	—	340	Preoperative
	104	60	125	11
	100	68	205	14
44	40	2	88	Preoperative
	82	25	135	4

In Cases 30 and 34, section of the sphincter led to considerable improvement in the function of a chronically diseased pancreas. In Case 36, although the patient lost all her symptoms and gained 20 pounds in weight, the secretin test showed no evidence of improvement on two occasions; in addition, the patient developed typical chronic diabetes mellitus one year after.

The secretin test was found to be of value in patients with complete obstructive jaundice due to malignancy (Table 7). In four patients with carcinoma of the head of the pancreas, there was practically no response to the injection of secretin. Only a small amount of fluid containing a trace of amylase could be recovered. In case 64, on the other hand, the injection of secretin produced a large volume of water-clear pancreatic juice containing large amounts of amylase. The diagnosis of supraduodenal biliary tract carcinoma was confirmed at operation. Three anom-

TABLE 7

SECRETIN RESPONSE IN JAUNDICED PATIENTS WITH BILIARY-PANCREATIC CARCINOMA AND
IN PATIENTS WITH CIRRHOSIS OF THE LIVER

Case No	Total Volume (Cc).	Total Bicarbonate (Cc. N/10)	Total Amylase (Lagerlof Units)	Remarks
58	4	—	9	Carcinoma of head of pancreas
59	44	—	5	Carcinoma of head of pancreas
60	43	—	10	Carcinoma of head of pancreas
61	66	—	8	Carcinoma of head of pancreas
62	146	82	222	Carcinoma of ampulla of Vater, obstructing bile duct only
63	133	—	490	Carcinoma of common hepatic duct
64	118	62	186	Advanced cirrhosis of liver with complete stoppage of bile flow
65	295	64	15	Cholangitic cirrhosis with complete stoppage of bile flow

TABLE 8

AVERAGE SECRETIN RESPONSE IN PATIENTS WITH VARIOUS TYPES OF BILIARY-PANCREATIC DISEASE

No of Cases	Total Volume (Cc)	Total Bicarbonate (Cc.N/10)	Total Amylase (Lagerlof Units)	Type
13	260	144	765	Normal
9	157	111	485	Chronic cholecystitis
13	153	85	273	Acute pancreatitis (high serum amylase)
11	100	23	210	Chronic pancreatitis
11	116	71	371	Recurrent pancreatitis; normal serum amylase, normal pancreas by palpation
4	39	—	9	Carcinoma of head of pancreas with obstructive jaundice
1	146	82	222	Carcinoma of ampulla of Vater, obstructing bile duct only
1	133	—	490	Carcinoma of common hepatic duct
1	118	62	186	Advanced cirrhosis with severe jaundice
1	295	64	15	Cholangitic cirrhosis with severe jaundice

alous cases, however, were found. In Case 62, a carcinoma of the ampulla of Vater obstructed only the bile duct, so that the preoperative secretin

test elicited a normal response. In two patients with severe cirrhosis (No. 64 and 65), the almost complete suppression of bile secretion in association with a large flow of pancreatic juice in response to secretin suggested a preoperative diagnosis of organic obstruction in the biliary tract above the upper border of the duodenum.

Reflux of pancreatic juice through a T-tube in the biliary tract was attempted in fifteen patients with an intact sphincter of Oddi, by the use of secretin (Table 9). In ten of these, the experiment was repeated after producing spasm of the sphincter of Oddi and duodenal wall by

TABLE 9

COMPARATIVE VALUE OF SECRETIN AND OF CHOLANGIOGRAMS IN DEMONSTRATING A COMMON PASSAGEWAY (SPHINCTER OF ODDI INTACT)

Case No.	Highest Concentration of Amylase in Bile (Mg Glucose per 100 Cc)		Demonstration of Pancreatic Duct by Cholangiogram
	Without Spasm	Spasm Produced by Morphine	
14	2280	2890	+
15	51000	11000 (*30,000)	+
17	0	0	0
20	0	0	0
66	0		0
67	0		0
68	0	0	0
69	0		0
70	0		0
71	142	1176 (*3,220)	+
73	128	39	+
75	2500		0
78	8000	8500	+
79	6000	0	+
80	17000	61000 (*18,000)	+

* Spasm of sphincter of Oddi produced by introduction of hydrochloric acid into duodenum

the administration of morphine. In three patients spasm of the sphincter of Oddi was induced by instilling hydrochloric acid into the duodenum. Cholangiographic studies confirmed the presence of a common passageway in all but one patient in whom pancreatic enzymes were detected in the T-tube bile.

The residual resistance of the duodenal wall after destruction of the sphincter of Oddi was sufficient to direct the flow of pancreatic juice through an open T-tube (Table 10). The results not only confirmed the presence of a common passageway as proven by cholangiographic studies,

but showed that the secretin test was more sensitive. In four patients (Nos. 35, 37, 48, 51), reflux of pancreatic juice proved the presence of a common passageway, while cholangiographic studies, at operation and postoperatively, failed to visualize the pancreatic duct.

All specimens of bile recovered through the T-tube were tested for the presence of activated trypsin, by incubation with a Mett tube for twenty-hour hours. In no case was there any evidence of activated trypsin, proving that the presence of the pancreatic enzymes was due to direct reflux of pancreatic juice and not to duodenal reflux

TABLE 10

COMPARATIVE VALUE OF SECRETIN AND OF CHOLANGIOGRAM IN DEMONSTRATING A COMMON PASSAGEWAY (SPHINCTER OF ODDI SECTIONED)

Case No.	Highest Concentration of Amylase in Bile (Mg Glucose per 100 Cc)		Visualization of Pancreatic Duct by Cholangiogram
	Without Producing Spasm	Spasm Produced by Morphine	
18	57,500	27,500	+
23	4,000	—	+
24	8,500	1,000	+
27	1,500	6,000	+
28	815	605	+
30	6,500	—	+
35	7,000	8,500	0
37	2,000	9,500	0
46	49,500	76,000	+
48	25	85	0
51	135	250	0
72	2,350	—	+
74	10,000	48,500	+
76	9,000	22,000	+
77	11,800	10,500	+

The variations in the concentration of amylase produced by spasm of the sphincter and duodenal wall by the use of morphine was due to the distance above the papilla at which the bile and pancreatic ducts joined. Thus in Case 27, spasm reduced the maximum concentration of amylase from 8500 to 1000 units. In this patient the ducts, as shown by cholangiographic studies, joined close to the papilla. On the other hand, in Case 76, in which the maximum concentration of amylase rose from 9000 to 22,000 units, following spasm, the ducts joined at a considerable distance above the papilla.

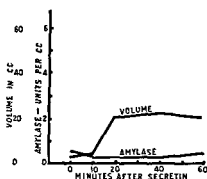
The observation that the color of the duodenal juice collected during the secretin test is a good indication of gallbladder function (Lagerlof, Diamond) was confirmed in this study. In patients whose gallbladder

showed good function by the Graham test, many of the samples of duodenal juice were water-clear. In patients in whom the gallbladder failed to visualize by x-ray, or in postcholecystectomy patients, all samples of duodenal juice were bile stained.

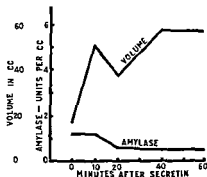
COMMENT

It was felt that if the secretin test were to prove of practical value in clinical surgery, the test should be simplified as much as possible. Although Lagerlof felt that a submaximal dose of secretin would show greater differences between the normal and diseased pancreas, we felt that the maximum response of the pancreas to a large dose of secretin

EFFECT OF OPERATION ON SECRETIN TEST



2 WEEKS AFTER OPERATION
TOTAL VOLUME 90 CC.
TOTAL AMYLASE 20 UNITS



6 MONTHS AFTER OPERATION
TOTAL VOLUME 200 CC.
TOTAL AMYLASE 121 UNITS

Fig 170

uld prove to be a more valuable index. Accordingly, our dosage was about one and one-half times greater than Lagerlof's, and was given to all patients without regard to their weight.

The average figures for total volume, bicarbonate and amylase in each group of patients, as summarized in Table 8, show that (1) the secretin test reflects the increasing destruction of the pancreas by recurrent inflammation due to pancreatitis, and (2) the secretin test is of value in the differential diagnosis of obstructive jaundice due to malignancy. Although there are some exceptions to this latter observation, some of which we presented, in general carcinoma of the head of the pancreas which has extended sufficiently to cause complete obstruction of the bile duct will have also obstructed both the main and accessory pancreatic ducts.

The presence of a common passageway between the bile and pancreatic ducts as an etiologic factor in the production of both cholecystitis^{11, 12, 13} and pancreatitis^{14, 15, 16, 17, 18} has made the diagnosis of this anatomical condition a matter of great importance. Progress in the technic of cholangiographic studies to visualize the pancreatic duct has enabled us to demonstrate its presence in about 50 per cent of operative patients. Our results, using secretin to deliberately produce pancreatic reflux,¹⁷ indicate that it is probably a more accurate method to diagnose the presence of a common passageway.

Although we followed Lagerlof's procedure and collected and analyzed four different samples during the secretin test, our results indicate that the total volume, bicarbonate and amylase units were of diagnostic value. It would seem, therefore, that the collection of one hour secretion of duodenal juice as one sample, following the injection of secretin, would be sufficient. Lipase and trypsin analysis were not done owing to the rapid destruction of these enzymes after collection of the duodenal juice. Simple rapid methods for the determination of amylase, lipase and trypsin would be of great value in making the secretin test practical and complete.

SUMMARY

The secretin test was found to be of value in:

1. The diagnosis of chronic pancreatitis.
2. The evaluation of the results of operation for pancreatitis.
3. The differential diagnosis, in patients with obstructive jaundice, between carcinoma at the head of the pancreas and carcinoma involving the supraduodenal part of the biliary tract.
4. The diagnosis of a common passageway between the bile and pancreatic ducts.
5. The estimation of the functional status of the gallbladder.

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CLINICS ON OTHER SUBJECTS

TUMOR CELLS IN DIAGNOSTIC SPECIMENS: THEIR DETECTION AND SIGNIFICANCE

H. M. ZIMMERMAN, M.D.* AND RUTH LUBLINER, M.D.†

In recent years increasing attention has been focused on the study of exfoliated cells in tumor diagnosis. The reason for this, of course, is the constant striving for the early detection of new growths, even before definite symptoms develop. An impetus for such study has in part been the result of the publication by Papanicolaou and Traut¹ on the identification of cancer cells in vaginal smears, although Papanicolaou himself² and others^{3, 4, 5, 6, 7, 8, 9} had called attention earlier to this means of diagnosis.

Various methods have been employed in different laboratories for the collection, preparation and study of diagnostic specimens. Each method has certain advantages and limitations; these will be discussed in their proper place below. Essentially, this paper concerns itself with the techniques employed in the laboratories of the Montefiore Hospital and with the results they have yielded.

It is not the intention of the present writers to include a discussion of routine biopsy procedures. They have a strong conviction that the biopsy method of diagnosis is still the most certain and that these other methods are to be regarded only as accessory aids. Their use in lieu of a biopsy should be countenanced only when the latter is not feasible. Certainly, other diagnostic procedures should not be delayed to allow time for repeated efforts to obtain specimens of exfoliated cells. These, however, are of great value under certain circumstances and occasionally they may offer the first and perhaps the only available evidence of malignancy.

TUMOR CELLS IN PLEURAL AND PERITONEAL FLUIDS

Pleural and abdominal effusions as a rule are not early signs of malignancy. They may occur as the result of metastases to the respective

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serous surfaces, when they frequently contain exfoliated tumor cells. Only the presence of such cells in fluid specimens is significant; their absence may be the result of defective technic in withdrawing or preserving the specimen, or of preparing it for microscopic study. In some instances the tumor cells may be masked by hemorrhage or by overwhelming numbers of desquamated mesothelial cells. In general, however, the recognition of tumor cells in these specimens is not difficult, especially if the material is prepared for microscopic study as follows:

1. Centrifuge the specimen (from a few cubic centimeters to several liters) for five minutes at a low rate of speed (2000 r p m).
2. Fix any solid material and sediment for twelve to twenty-four hours in either 10 per cent formalin or formol-alcohol (1 part of 37 per cent formaldehyde to 9 parts of 95 per cent alcohol).
3. Dehydrate in 80 per cent, 95 per cent and absolute alcohol. Centrifuge specimen after each change, if necessary.
4. Clear in aniline oil over night.
5. Two changes of xylene, one-half hour each.
6. Mixture of paraffin and xylene, equal parts of each, one hour.
7. Two changes of paraffin, 48°, one hour each.
8. Embed in Tissuemat, 56° to 58°, one hour.
9. Cool rapidly in ice water containing chopped ice.
10. Break tube to remove paraffin block at bottom.
11. Cut and stain with hematoxylin and eosin as for routine paraffin sections.

The examination of body fluids by this cell block method has several advantages over the smear method. It is less time-consuming, the chances of finding abnormal cells are greater since centrifugation serves to concentrate them, and the natural grouping of cells in nests and cords is preserved. In smears the cells are seen singly or in clumps and the original structures are disrupted. The cytology of the single cell is not the most important feature of the cell block, as it is in the smear, but rather the grouping of cells and their relation to one another. Single cells in the cell block preparation tend to be round, swollen and vacuolated, with the nuclei in eccentric positions. This is true for tumor cells as well as for mesothelial cells.

Some difficulty may be encountered in the differential diagnosis between tumor cells and non-neoplastic mesothelial cells. This is occasioned by a feature which is common to all cells in body fluids, namely, the tendency to form acinar structures. Helpful factors in differentiation are the usual anaplasia of tumor cells and the uniformity in appearance of normal mesothelial cells, but these are not always clear-cut. Mesothelial cells which are desquamated into the pleural or peritoneal cavities in the course of inflammatory processes often show a disproportion between the

size of the nuclei and the cytoplasm. There is also a tendency to nuclear hyperchromia. Failure of such cells to form masses or clumps, however, provide suggestive evidence of their nonmalignant nature.

During the past year fluid from the pleural or peritoneal cavities was examined from ninety-six patients who had clinical evidence of cancer. The primary sites of the tumors are given in Table 1. Of these ninety-six patients, sixty-nine had tumor cells, whereas twenty-seven had no such cells on repeated examination. The total number of examinations performed on this negative group of twenty-seven patients was eighty-seven. Evidence of carcinomatous implants on the pleural or peritoneal surfaces was found at necropsy in thirty-four of the sixty-nine positive cases.

TABLE 1
RESULTS OF EXAMINATION FOR TUMOR CELLS IN BODY FLUIDS

Cases	Site of Neoplasm	Positive	Negative
29	Breast.....	22	7
26	Lung.....	18	8
13	Ovary.....	13	0
8	Rectum or colon.....	3	5
4	Stomach.....	4	0
2	Pancreas.....	2	0
2	Gallbladder.....	1	1
2	Kidney.....	0	2
2	Cervix.....	1	1
1	Esophagus.....	0	1
1	Mastilla.....	0	1
1	Nasopharynx.....	0	1
1	Testis.....	1	0
4	Abdominal carcinomatosis, primary site undetermined.....	4	0
—		—	—
96		69	27

In two instances where no tumor cells were found in the cell blocks of the fluid, necropsy failed to disclose involvement of the serous surfaces by carcinomatous tissue. In two instances, on the other hand, tumor cells were not found during life, but necropsy revealed pleural and peritoneal metastases. In addition to the total of thirty-four positive cases verified by postmortem examination, sixteen more had biopsy confirmation of tumor involvement of the serous surfaces. In three other cases which were negative for tumor cells in the fluid, biopsies of the pleura or peritoneum revealed carcinoma. There was no opportunity to confirm the diagnosis of tumor cells in cell blocks of fluids by either necropsy or biopsy in the remaining nineteen positive cases.



Fig 171 —The following photomicrographs are of material prepared by the cell block method and stained with hematoxylin and eosin unless stated otherwise
 A (Case I), Group of tumor cells in pleural fluid. $\times 750$.

The microscopic appearance of the formed elements in the cell blocks of body fluids are illustrated in the following cases.

CASE I.—R. P. was a 69 year old woman with carcinoma of the left breast which was confirmed at necropsy. Metastases were found in the lungs and pleura. Following the onset of bilateral pleural effusion, a cell block of the fluid revealed a group of tumor cells (Fig. 171, A).

CASE II.—A. R. was a 65 year old woman who had a cystadenocarcinoma of the ovaries with diffuse spread over all peritoneal surfaces. About 12 cc. of hemorrhagic fluid were obtained by paracentesis and prepared by the cell block method. Many tumor cells were present in mitotic division and some were multinucleated (Fig. 171, B).

CASE III.—L. B. was a 63 year old man who had pleural and pericardial effusions for nine months. There was no evidence of malignancy. The clinical and laboratory data suggested pernicious anemia. A cell block of the pleural fluid disclosed abnormal cells (Fig. 171, C). The pericardial fluid contained acinar structures composed of cells which were suggestive of tumor cells (Fig. 171, D). Six months later the pericardial fluid still contained acini formed by cells which were now interpreted as hyperplastic mesothelial elements (Fig. 171, E).

CASE IV.—B. C. This 48 year old man entered the hospital with a clinical diagnosis of peritoneal carcinomatosis secondary to colloid carcinoma, primary site undetermined. This was confirmed by two biopsies and by the cell block made of abdominal fluid (Fig. 171, F). At autopsy, three months later, the diagnosis was established of pseudomyxoma peritonei, probably secondary to mucocele of the appendix.

CASE V.—A. T. was a 39 year old woman with carcinoma of both breasts. Bilateral pleural effusions developed. A cell block prepared from 250 cc. of

B (Case II), There are large polyhedral tumor cells with hyperchromic nuclei in the peritoneal fluid. Some cells are in mitotic division and others are multinucleated. The smaller elements are mesothelial cells. $\times 395$.

C (Case III), The atypical cells in the pleural fluid have deep acidophilic cytoplasm and large hyperchromic nuclei. $\times 545$.

D (Case III), The atypical cells in the pericardial fluid form an acinar structure. $\times 545$.

E (Case III), In this specimen of pericardial fluid removed six months after that illustrated in D, the columnar cells appear quite regular in size and shape. Atypical cells were not present. Diagnosis—hyperplastic mesothelium. $\times 545$.

F (Case IV), Tall columnar cells in peritoneal fluid are arranged in single layers to form strands and incomplete acini. Although bizarre cells and mitoses are absent, the diagnosis of adenocarcinoma was made. Necropsy disclosed a pseudomyxoma peritonei. $\times 260$.

G (Case V), Clusters of malignant cells in pleural fluid from carcinoma of the breasts. $\times 545$.

H (Case VI), Vacuolated tumor cells in pleural fluid from carcinoma of the lung. $\times 545$.

(A to H reduced one half from original microphotographs)

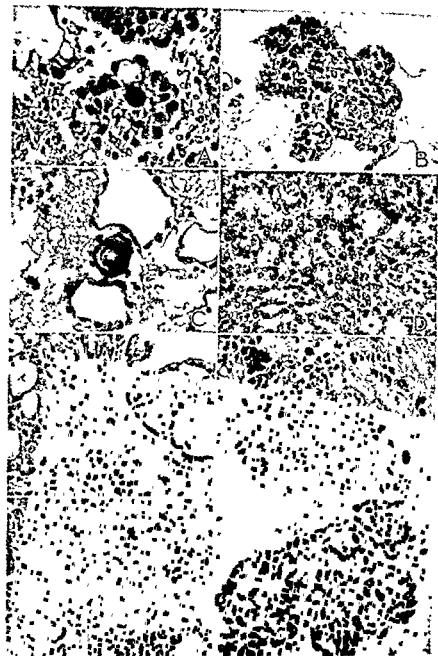


Fig 172.—*A* (Case VII), *Colloidal fluid from case of adenocarcinoma of ovary*, . . .

B (Case VIII), Tumor cells in abdominal fluid. Note acina. 1 mass
X395

C (Case VIII), Calcific deposit in sediment of abdominal fluid. The acinar structures probably represent mesothelial cells rather than adenocarcinoma. These findings suggested the diagnosis of ovarian carcinoma. X395

D (Case VIII), Adenocarcinoma in biopsy of axillary lymph node H and E stain, $\times 895$.

yellow, turbid fluid disclosed many vacuolated tumor cells in clusters (Fig. 171, G). The primary site of the tumor could not be determined from these cells.

CASE VI.—E. F., a 52 year old woman, had a small adenocarcinoma of the upper lobe of the right lung with widespread metastases and massive pleural effusion on the right. A cell block of 1 liter of this hemorrhagic fluid yielded numerous vacuolated tumor cells (Fig. 171, H) which were indistinguishable from those seen in Figure 171 G

CASE VII.—L. S. was a 62 year old woman with abdominal carcinomatosis from an ovarian adenocarcinoma. Two and one-half gallons of hemorrhagic abdominal fluid were centrifuged and a cell block was prepared which showed tumor cells arranged in cords and pseudorosettes (Fig. 172, A).

CASE VIII.—M. S. For three years this 50 year old woman had a chronic, non-productive cough. Hemoptysis occurred one and one-half years later and massive ascites three months before her admission to the hospital. A large, hard mass was palpated in the left side of the abdomen. A cell block of abdominal fluid at this time disclosed tumor cells with a tendency towards acinar formation (Fig. 172, B). In other microscopic fields the presence of calcific deposits suggested the diagnosis of ovarian carcinoma (Fig. 172, C). Biopsy of an axillary lymph node (Fig. 172, D) revealed metastatic adenocarcinoma, and a diagnosis of breast carcinoma was entertained. A biopsy was then made of the bronchus of the right lower lobe and it disclosed an anaplastic carcinoma (Fig. 172, E). Diagnosis established—bronchogenic carcinoma.

CASE IX.—P. K., a 61 year old man, had a luetic aneurysm of the ascending aorta. There was much thickening of the visceral and parietal pleurae with encapsulated fluid. There was no evidence of a neoplasm, and this was confirmed later at necropsy. A cell block prepared from 100 cc. of pleural fluid, however, disclosed numerous atypical cells (Fig. 172, F).

Comment.—The foregoing cases emphasize certain facts concerning the study of cellular constituents in pleural and peritoneal fluids.

1. Tumor cells are often but not always present in body cavity fluids, even in cases of pleural and peritoneal carcinomatosis.

2. Irritative phenomena may so alter the mesothelium that atypical

E (Case VIII), Anaplastic carcinoma in biopsy of bronchus from right lower lobe. H. and E. stain; $\times 325$

F (Case IX), Numerous atypical cells in cell block from pleural effusion in a case of syphilitic aortic aneurysm. A neoplasm was not suspected clinically and was not found at necropsy. $\times 245$.

G (Case X), Adenocarcinoma in biopsy of lymph node. Primary site questionable. H. and E. stain, $\times 305$

H (Case X), Malignant cells in cell block of sputum. Diagnosis of bronchogenic carcinoma established. $\times 395$.

(A to H reduced one half from original microphotographs)

cells are produced which often cannot be distinguished from neoplasia. Such cells have a tendency to form acini.

3. Relatively benign tumors such as pseudomyxoma peritonei often cannot be distinguished from more malignant tumors.

4. Many tumor cells in body fluids become vacuolated.

5. The primary sites of malignant neoplasms frequently cannot be determined from the exfoliated cells.

6. In spite of these several disadvantages inherent in the cell block method of study of body fluids, considerable help is frequently obtained both in the recognition and localization of malignancy

TUMOR CELLS IN SPUTA AND BRONCHIAL SECRETIONS

Gower¹⁰ and Wallner and McDonald¹¹ have written recently on the value of the cytologic examination of sputum in the diagnosis of pul-

TABLE 2

RESULTS OF EXAMINATION OF SPUTA AND BRONCHIAL SECRETIONS IN THIRTY-TWO CASES OF PULMONARY CARCINOMA

Method	Tumor Cells Present	Atypical Cells	Tumor Cells Absent
Cell block	6	4	8
Smear	4	5	5
Total	10	9	13

monary malignancy Diggs,¹² Herbut¹³ and Herbut and Clerf^{14, 15, 16} have stressed the finding of cancer cells in bronchial secretions. The present writers have employed both the cell block and the smear methods in the study of sputa as well as bronchial secretions.

The results with sixty patients on whom a total of 153 examinations were performed (sixty-three cell blocks and ninety smears) have served to emphasize certain facts of the examination which are of prime importance. One is the necessity of exercising great care in the collection of the specimen. Only fresh sputum should be employed, and this must be free from gastric contents and the mucous secretions from the posterior nasopharynx. Whenever possible, the sputum examination should be followed by a study of smears of the bronchial secretions obtained by aspiration during bronchoscopy. Multiple examinations of the same patient are essential, and it should be realized that this is time-consuming. Even then, the results obtained with thirty-two proved cases of pulmonary carcinoma in this hospital are not exceedingly gratifying (Table 2). On repeated examination only nineteen patients were found to have

neoplastic or atypical cells in their secretions and fully thirteen patients had no tumor cells. It must be emphasized at this point that atypical cells are not necessarily neoplastic cells. Suppurative processes in the lungs and bronchi, and especially tuberculosis, frequently produce morphologic changes in the respiratory epithelium. Cells which are desquamated from this epithelium have an atypical appearance.

Conversely, it should be borne in mind that bronchogenic tumors may produce complete block, in which case tumor cells would be absent from both sputum and bronchial secretions. The practice of obtaining a biopsy of abnormally appearing bronchial mucosa during bronchoscopy for the aspiration of secretions is therefore to be encouraged.

Experience has demonstrated the fact that bronchial washing and aspiration is a particularly valuable procedure in the diagnosis of tumors of the right upper lobe. Neoplasms in this location are beyond the field of visualization on bronchoscopy, which precludes biopsy. In two cases included in Table 2, smears of the bronchial secretions from the upper lobe of the right lung were positive for tumor cells.

It has been the practice in this hospital to prepare cell blocks of sputum when there are copious amounts. Centrifugation serves to concentrate the desquamated cells. But occasionally the small quantity of sputum does not permit this technic, in which case fresh smears are fixed and stained by the Papanicolaou method.* Bronchial secretions, on the other hand, are almost always prepared for study by the smear method. When

* The method originally described by Papanicolaou and Traut¹ has been slightly modified in this laboratory and is as follows

1. Fix thin smears immediately before drying in equal parts of 95 per cent alcohol and ether for five to fifteen minutes.
2. Rinse in 70 per cent alcohol, then in 50 per cent, and finally in distilled water.
3. Stain in Harris' hematoxylin for ten minutes
4. Wash in distilled water.
5. Decolorize in four to five changes of 0.5 per cent hydrochloric acid water, pouring off and on in jar
6. Rinse thoroughly in tap water.
7. Place for one minute in weak lithium carbonate (3 drops of a saturated solution in 100 cc. water).
8. Rinse in tap water
9. Pass through 50, 80 and 95 per cent alcohol.
10. Stain for five minutes (using a stop watch) with Papanicolaou's orange G.
11. Rinse in three changes of 95 per cent alcohol, using Coplin jars
12. Stain for five minutes in Papanicolaou's EA 36.
13. Rinse in three changes of 95 per cent alcohol Use fresh jars and fresh alcohol.
14. Absolute alcohol, xylene, mount in clarite

Use a water bath for preparing the stains. They tend to precipitate and must be shaken occasionally, heated on the water bath, and filtered. Each solution is filtered separately before combining to make the final stain.

bronchial washings with saline are resorted to, the quantity of aspirated material again determines which technic will be followed.

The group of cases which follow serve to illustrate some of these conclusions

CASE X.—S. R., a 56 year old man, had a cough and expectoration for one and one-half years. Bronchoscopic examination was negative, but biopsy of a lymph node later revealed metastatic adenocarcinoma (Fig 172, *G*). At about this time a cell block prepared from the sputum was found to contain clusters of tumor cells (Fig. 172, *H*), and helped to establish the diagnosis of bronchogenic carcinoma, which was later confirmed by x-ray examination.

CASE XI.—W. C. was a 45 year old man who had cough, night sweats and expectoration (negative for acid-fast organisms). Smears of the sputum stained by the Papanicolaou method disclosed tumor cells (Fig 173, *A*). Bronchoscopy, roentgenographic findings and thoracotomy proved the diagnosis of a pulmonary carcinoma in the right upper lobe (Fig 173, *B*).

CASE XII.—C. K., a man 64 years of age, had pain in the lower part of the chest on the right side for about one year. A cell block of the sputum revealed atypical cells (Fig 173, *C*). Metastatic adenocarcinoma was found on biopsy of the right eighth rib. Necropsy proved the presence of a primary carcinoma in the upper lobe of the right lung.

CASE XIII.—B. G., a man of 68 years, entered the hospital with a diagnosis of pulmonary carcinoma. Smears of the sputum stained by the Papanicolaou method showed clusters of indistinct pink cells which were diagnosable only as questionable tumor cells (Fig. 173, *D*). Postmortem examination revealed a nonkeratinizing squamous cell carcinoma of the lower lobe of the right lung (Fig 173, *E*).

Orange G

Orange G	0.5	gm
95% alcohol	100	cc.
Phosphotungstic acid	0.015	gm

EA 36

Light green 0.5% in 95% alcohol	45	cc.
Bismarck brown 0.5% in 95% alcohol	10	cc.
Eosin Y 0.5% in 95% alcohol	45	cc.
Phosphotungstic acid	0.2	gm
Lithium carbonate, saturated aqueous solution	1	drop

Acidophilic cells vary in color from orange to red

Basophilic cells are green or blue

Fragments of tissue and red blood cells are orange-green

CASE XIV.—I. A., a man 69 years of age, had cough with blood-streaked sputum for five months. His condition was too poor for bronchoscopy and x-ray examination merely revealed clouding of the right upper lobe. The differential diagnosis lay between an inflammatory lesion and carcinoma. A cell block of the sputum revealed tumor cells (Fig. 173, *F*)

CASE XV.—J. V. was a 58 year old man who entered the hospital with a diagnosis of carcinoma of the rectum and metastases to lungs and spine. Sig-moidoscopy revealed a benign rectal polyp and the findings on x-ray examination of the vertebral column were interpreted as traumatic arthritis. Bronchoscopy failed to show any endobronchial lesion and no significant amount of secretion. Bronchial biopsy was negative, but a Papanicolaou smear of the bronchial secretions done at the same time was positive for tumor cells (Fig. 173, *G*). An exploratory thoracotomy was then performed reluctantly and revealed a tumor mass, 4 cm. in diameter, in the peripheral portion of the right upper lobe. Because the patient's condition did not permit pneumonectomy, the tumor was excised locally and was found to be an anaplastic carcinoma on microscopic examination (Fig. 173, *H*).

Comment.—The value of a thorough search for desquamated tumor cells in sputa and bronchial secretions needs no further emphasis. This has been amply demonstrated by the case histories which have just been detailed. Lest overconfidence in the cell block and Papanicolaou smear methods of study result, a word of caution is indicated. In two ways these methods sometimes fail. Tumor cells may be absent both in sputa and bronchial secretions, even on repeated examination, in the presence of a known carcinoma of the lungs. This happened in thirteen of our thirty-two cases. And in rare instances atypical cells are found which suggest malignancy when a pulmonary neoplasm is not present. This occurred in one of our patients who was subjected to a pneumonectomy and who was found to have a lung abscess.

It is worth recording that in our experience tumor cells have not been found in the bronchial secretions from patients who have pulmonary metastases. This is difficult to understand since erosion into bronchi by metastatic tumors can and does occur.

TUMOR CELLS IN GASTRIC CONTENTS

Results of examination for tumor cells in materials removed from the stomach have almost invariably been disappointing in this hospital. Other writers,^{17, 18, 19, 20} however, have had better success. To be of value, the cytologic examination of gastric contents should be performed in early suspected cases of malignancy. Since most of the cases of gastric carcinoma at Montefiore Hospital have been in far advanced stages, cytologic examinations were undertaken not as an aid in diagnosis but

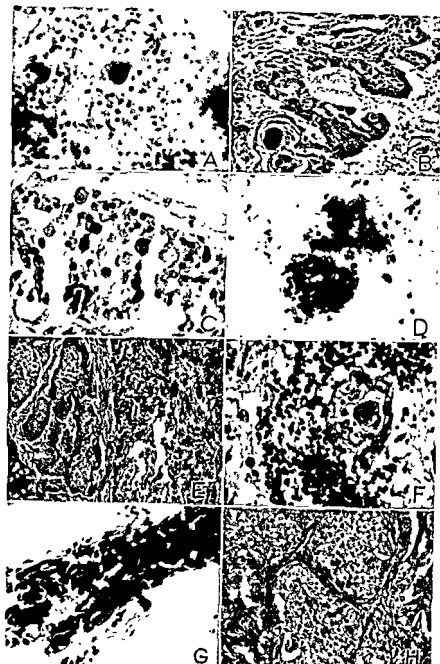


Fig 173—*A* (Case XI), Smear of sputum stained by Papanicolaou method shows a malignant cell (pink cytoplasm) $\times 395$

B (Case XI), Biopsy from right upper lobe bronchus to show carcinoma H and E stain; $\times 185$

C (Case XII), Cell block of sputum. Note atypical cells $\times 545$

D (Case XIII), Papanicolaou smear of sputum to show clusters of questionable tumor cells which had pink cytoplasm. $\times 305$.

rather to test the validity of such examinations. In all, eleven cases of gastric malignancy were studied and the diagnoses verified later by biopsy or at necropsy. In only one of these patients were tumor cells found in the fluid.

The disappointing results were chiefly attributable to the nature of our cases; i.e., the tumors were all large and necrotic with viable cells present only in the depths of the lesions. Presumably, the cells which are desquamated into the stomach from such necrotic lesions are rapidly digested. This emphasizes the need for study of fresh material which should be uncontaminated by sputum.

CASE XVI.—L. E. was a 55 year old woman with symptoms of six months' duration characterized by constipation, anorexia, nausea and vomiting. The patient lost 35 pounds in weight and developed cramplike, epigastric pain. Exploratory laparotomy disclosed an inoperable carcinoma in the distal third of the stomach with metastases to the adjacent omentum and right lobe of the liver. Gastric aspiration yielded 50 cc. of cloudy yellow fluid which was centrifuged and prepared for study by the cell block method. Numerous desquamated epithelial cells, some leukocytes, and clumps of degenerating large polyhedral cells were present. The latter were suggestive of carcinoma (Fig. 174, A).

TUMOR CELLS IN URINE

It is the opinion of most writers^{21, 22, 23, 24} that smears of urine sediment are of value in the diagnosis of neoplasia in the urinary tract. In this hospital, tumor cells were found in the urine of one patient who had an adenocarcinoma of the kidney (proved by necropsy), one who had a transitional cell carcinoma of the renal pelvis (proved by biopsy), and two who had carcinomas of the urinary bladder (also proved by biopsy). Of course, many more urine specimens of other patients were examined with negative results, but in none of them was a urinary tract neoplasm demonstrable at any time. In other words, there were no instances of falsely positive examinations. The limited number of patients with malignancy of the urinary tract who were studied does not warrant any conclusions as regards the general reliability of this method of examination.

E (Case XIII), Photomicrograph of bronchus of lower lobe of right lung. Nonkeratinizing squamous cell carcinoma. H. and E. stain; $\times 185$.

F (Case XIV), Note tumor cells suggestive of keratinizing squamous cell carcinoma in cell block of sputum. $\times 545$.

G (Case XV), Papanicolaou smear of bronchial secretion from right upper lobe. Note numerous tumor cells (bronchial biopsy done at same time was negative for tumor cells). $\times 545$.

H (Case XV), Photomicrograph of anaplastic carcinoma in right upper lobe. H and E stain; $\times 185$.

(*A* to *H* reduced one half from original microphotographs)

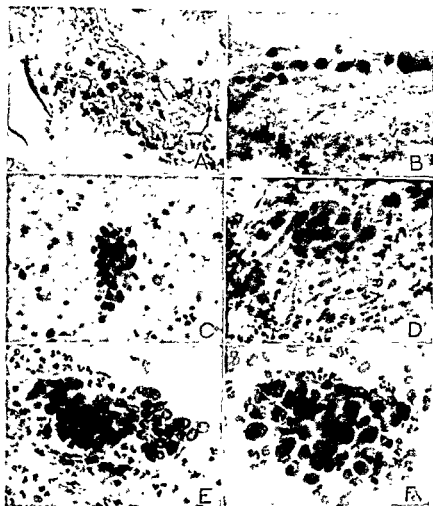


Fig 174 — *A* (Case XVI), Badly degenerated cells suggestive of carcinoma are seen in the cell block of aspirated gastric fluid $\times 545$

B (Case XVII), Questionable tumor cells are seen in the Papanicolaou smear of the urine sediment from a case of carcinoma of the bladder $\times 545$

C (Case XVIII), Cluster of tumor cells in urinary sediment stained by Papanicolaou method. Diagnosis of transitional cell carcinoma of renal pelvis established by biopsy $\times 545$

D (Case XIX), Vaginal smear shows atypical cells. Biopsy of cervical tissue confirmed

been removed three years previously.

F (Case XXI), Tumor cells in large advanced case of carcinoma of the

(*A* to *F* reduced one half from mic.)

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CASE XVII.—J. R., a man 77 years of age, developed painless hematuria, then swelling of the inguinal lymph nodes. Low back pain followed and, finally, swelling of the entire right lower extremity. Metastatic carcinoma was found in a biopsy of an inguinal lymph node. Papanicolaou smears of urine sediment revealed questionable tumor cells (Fig 174, *B*). These examinations were followed by a biopsy of the urinary bladder, which disclosed the primary site of a carcinoma.

CASE XVIII.—M. H., a man of 62 years, had hematuria, frequency and nocturia for about a year. There was increasing weakness and a loss of weight. Intravenous and retrograde pyelography showed an obstruction of the right ureteropelvic junction. Smears and cultures for acid-fast organisms were negative. Repeated smears of the urine sediment contained numerous cells of varied morphology. Leukocytes, macrophages, squamous epithelial cells and desquamated renal tubular cells were present. Among them were found clusters of atypical cells of different sizes and shapes and with hyperchromic nuclei. These were interpreted as representing tumor cells (Fig. 174, *C*). A right nephrectomy was then performed and the diagnosis of a transitional cell carcinoma of the renal pelvis established.

Comment.—It is not intended to emphasize the early diagnostic value of this form of urinary sediment examination with these illustrative cases. The clinical histories, physical examinations, and special procedures (including biopsy examination) were adequate to establish the diagnosis without the aid of the urinary sediment smear. The important facts which these cases emphasize are that desquamated tumor cells do occur in specimens of urine and that these cells can be recognized with ease. Perhaps in earlier cases which present more serious diagnostic problems this type of examination could be of more value.

TUMOR CELLS IN VAGINAL SMEARS

In the twenty years which have elapsed since the publication by Papanicolaou² of his method for cancer diagnosis, and especially within the past five years, an imposing literature has appeared on the subject. This has reached such proportions that it is hardly possible for considerations of space to evaluate each contribution individually. Many of these papers, however, are included in the reference list.²⁵⁻⁴⁷

All writers are agreed on the desirability of aids to earlier diagnosis of uterine and cervical cancer. The difficulties in diagnosis before the occurrence of definite symptoms, such as bleeding, are too well known to require repetition. It is also generally conceded that endometrial and cervical biopsies are all too frequently negative in the presence of definite malignancy. Fremont-Smith, Graham and Meigs³⁰ estimate that this

occurs in 10 per cent of cervical cancers. Any method of diagnosis, therefore, which would contribute to a reduction in the number of undiagnosed early cases would be of enormous value. There appears to be little doubt that the accumulated experience with the Papanicolaou smear technic indicates that this method has such value.

It should not be assumed, however, that the vaginal smear solves entirely the problem of early diagnosis. The smear fails to detect malignant disease in approximately 20 per cent of endometrial and 10 per cent of cervical cancers.³⁰ It also yields "false positive" results variously estimated at from 1 to 2 per cent. To help avoid such diagnostic errors it is clearly indicated that the smear method be combined with surgical biopsy in "positive" cases.

The vaginal smear has been instituted as a routine procedure in many Cancer Detection Clinics because of its reliability in noncancerous cases. In the Cancer Detection Clinic of the Montefiore Hospital, between March 1947 and July 1948, vaginal smears were made of 981 patients. Every female, regardless of age and preceding history, who reported to the Clinic had such an examination. Two smears were prepared in each instance, fixed promptly before drying in ether-alcohol solution, and stained by the Papanicolaou method as outlined above. Atypical cells were found in the smears of but nine patients, in only one of whom was a malignant neoplasm verified (Case XIX). The atypical cells were definitely due to chronic cervicitis in one instance (Case XX) and probably due to this cause in the others.

CASE XIX—G. J., a 50 year old woman, came to the Cancer Detection Clinic for a routine examination. She was still menstruating, but the duration of her periods which formerly lasted five days had increased to ten. The cervix was large, irregular, hard and granular with a patulous os through which projected a polyp which measured 8 mm. in diameter. The polyp bled easily on examination. A vaginal smear disclosed atypical cells suggestive of malignancy (Fig. 174, D). A biopsy of the polyp confirmed the diagnosis of early carcinoma.

CASE XX—B. L., a 51 year old woman, had had a supracervical hysterectomy three years previously for unknown reasons. In the Cancer Detection Clinic the cervix was found to be atrophic. Repeated vaginal smears contained atypical cells, some in nests and some scattered singly (Fig. 174, E). Cervical biopsy revealed chronic cervicitis but no evidence of malignancy.

A far higher incidence of positive vaginal smears has been reported from many gynecologic services than we found among the patients in the Cancer Detection Clinic. Two reasons probably account for this, both are based on the greater selectivity of the patients. Age was not a selective factor among our patients as it often is among women who present

themselves for examination in a gynecologic clinic. Many of our patients were in their twenties and thirties. Also, the fact that our patients came to the Cancer Detection Clinic rather than the outpatient gynecologic clinic indicates that they had no special signs or symptoms referable to the genital tract.

It cannot be claimed that proficiency in the cytology of the vaginal smear is easily attainable. This takes a large experience. The method is also time-consuming. It is frequently necessary to repeat the examination because the cells which are found are merely atypical—they are neither definitely neoplastic nor definitely normal components of the vaginal secretions. Of course, with more experience the uncertainties in diagnosis diminish, but they never quite vanish entirely. Furthermore, the certain knowledge that some definitely neoplastic cases fail to be revealed in the vaginal smears is both disconcerting and dictates longer study of the negative specimens. Even so, some known cases of malignancy are missed.

In fifteen advanced cases of uterine or cervical carcinoma, the present writers found the vaginal smears positive in eight. Three additional cases had atypical, but not definitely neoplastic, cells. In three more cases the smears showed only necrotic material; cells well enough preserved for identification could not be found. And the last case was negative on repeated examination.

CASE XXI. L. F., a woman of 60 years, entered the hospital for postmenopausal bleeding. An inoperable carcinoma in the lower portion of the uterus was found on exploratory laparotomy. The cervix and both ovaries were also involved. On vaginal smear, many leukocytes as well as tumor cells were present (Fig. 174, F).

Comment.—As an accessory aid in the diagnosis of malignancy of the genital tract, the vaginal smear method of Papanicolaou has an established place. Its sphere of greatest usefulness perhaps is in the gynecologic clinic where early signs of malignancy are sought. But it must be borne in mind that an appreciable number of cancers of the uterus and cervix escape detection by this method.

The value of the vaginal smear in the Cancer Detection Clinic among a wholly unselected group of women of all ages seems quite dubious. It is questionable whether the results justify the procedure on economic grounds and whether the time of trained personnel could not be devoted to more fruitful pursuits.

SUMMARY

An attempt has been made to evaluate the cell block and the Papanicolaou smear methods of tumor diagnosis in pleural and peritoneal

fluids, sputa and bronchial secretions, gastric contents, urine, and vaginal secretions. The advantages of each, and some of their limitations, are discussed. The technical procedures are described in detail. The cytology of tumor cells in diagnostic specimens is illustrated.

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THE DIFFERENTIAL DIAGNOSIS OF SPINAL CORD LESIONS

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EACH year a number of patients having surgically remediable conditions of the spinal cord or cauda equina are seen by the neurosurgeon after they have unnecessarily suffered pain or disability for months or years. Because of the acknowledged difficulties in making an early diagnosis in many such cases, sometimes simulating hysteria, disseminated sclerosis, tabes dorsalis, neuritis or arthritis, a brief discussion of the intraspinal conditions commonly treated by the neurosurgeon seems well worth while.

A really careful history of systemic and neurological symptoms, stressing the date of onset and details of the march of symptoms, should go a long way towards determining the general nature of the disease process; that is, whether it is neoplastic, inflammatory, traumatic or congenital in origin. The physical and neurological examinations, together with appropriate laboratory studies, then serve to clinch the diagnosis and indicate the level of the lesion, although in some instances this is impossible without exploratory laminectomy.

CLASSIFICATION

From the neurosurgical point of view, diseases of the spinal canal may be broadly classified as neoplastic, inflammatory, traumatic, congenital and "miscellaneous."

Neoplastic Lesions.—Neoplasms may be (A) extradural or (B) intradural. Most tumors of the extradural group are malignant and arise from structures outside the dura, while most intradural tumors arise from the spinal cord, nerve roots or meninges.

The intradural group may be subdivided into (1) intramedullary: those originating within the substance of the spinal cord such as ependymomas and other gliomas; and (2) extramedullary tumors: such as those arising from the nerve roots (neurofibromas) or meninges (meningiomas).

A. EXTRADURAL.—Extradural tumors (Fig. 175) usually produce symptoms and signs as the result of spinal cord *compression* rather than invasion. Most of them are malignant, such as tumors of the lymphoid series⁵ (lymphoblastoma, lymphosarcoma, Hodgkin's disease and

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others), metastatic carcinoma and sarcoma, chordoma; sympathicoblastoma, and so on. Sympathicoblastomas commonly arise in the mediastinum and extend locally by direct extension, while chordomas generally occur in the lumbosacral region where they result in extensive destruction of bone.¹⁶

Metastases to the spine are particularly apt to occur in the presence of carcinoma of the breast, prostate, thyroid,¹⁷ salivary glands or kidney (hypernephroma), and may affect the spinal cord either by compression, direct invasion or as a result of pathological fractures.

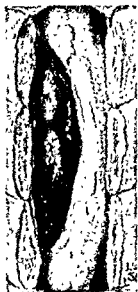


Fig 175 —Extradural tumor of spinal canal (sarcoma) (From El-berg, C. A. *Surgical Diseases of the Spinal Cord, Membranes, and Nerve Roots* Paul B Hoeber, Inc, New York, 1941)

A tumor such as a neurofibroma that extends through an intervertebral foramen is often referred to as a dumb-bell tumor because of its shape

Extradural tumors of bony origin include multiple myelomas, osteogenic sarcomas, round cell tumors, hemangiomas of the vertebrae,¹⁸ and the osteomatous proliferations associated with Paget's disease.^{17,24} Pathological fractures of vertebrae may be secondary to bone tumors such as multiple myelomas, or to other conditions such as osteitis fibrosa cystica.

Other extradural neoplasms of the spinal canal (which may also be intradural) include lipomas, neurofibromas, hemangiomas, and dermoid¹⁹ or epidermoid tumors.¹⁶

Certain tumors of the central nervous system may metastasize by

dissemination through the cerebrospinal fluid, particularly the medulloblastoma of children and young adults.

B INTRADURAL.—1. *Extramedullary.*—Neurofibromas (see Fig. 180) and meningiomas are the two commonest tumors in this category, and both are benign in the sense that if completely removed no recurrence may be expected. Either of these two tumors may, however, undergo malignant changes. It is worth emphasizing that neurofibromas may be multiple and are frequently associated with café-au-lait spots of the skin, or with neurofibromas or lipomas of the skin, peripheral nerves, cranial nerves, or other parts of the body (von Recklinghausen's disease). For gross and microscopic characteristics of these and other spinal tumors the reader is referred elsewhere.^{1,11,22,47,48,52}

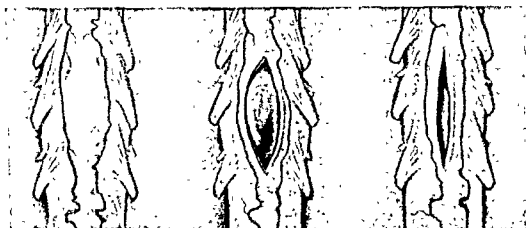


Fig 176—Intradural, intramedullary tumor of the spinal cord (From Elsberg, C. A.: *Surgical Diseases of the Spinal Cord, Membranes, and Nerve Roots* Paul B. Hoeber, Inc., New York, 1941)

2. *Intramedullary.*^{11,16,47,48,54}—Tumors of glial origin (Fig. 176) comprise about 10 to 20 per cent of all spinal cord tumors, the ependymoma being the commonest.²³ An ependymoma, and less frequently an astrocytoma, spongioblastoma or other types of glial tumor (rare in the spinal cord) may be associated with a syringomyelic cavity,^{2,23,42} while an ependymoma in the lumbar region may completely fill the subarachnoid space.¹⁶

Inflammatory and Infectious Conditions.—Foci of infection either by direct extension or hematogenous spread may lead to an extradural (epidural) abscess, granuloma, or to arachnoid adhesions. An extradural abscess usually arises from focal vertebral osteomyelitis, *Staphylococcus aureus* being the most prevalent organism.⁴ An extradural granuloma may simulate a neoplasm, both clinically and at operation.

Postinfectious arachnoiditis secondary to a regional infection is often

local or circumscribed compared to the more diffuse arachnoid adhesions secondary to meningitis or meningovascular syphilis.

A tuberculous abscess in the extradural space is generally a sequel of tuberculosis of the spine (*Pott's disease*) or of direct extension from a mediastinal or paravertebral tuberculous process (cold abscess) and may eventuate in tuberculous meningitis. *Pott's disease* may also lead to deformities of the spine capable of spinal cord compression.

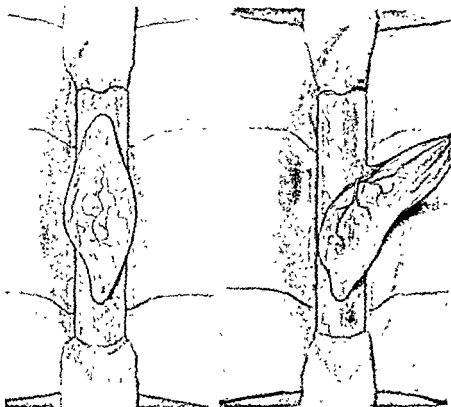


Fig. 177.—Extradural arachnoid cyst of the spinal cord (From Elsberg, C. A. *Surgical Diseases of the Spinal Cord, Membranes, and Nerve Roots* Paul B. Hoeber, Inc., New York, 1941.)

Traumatic Lesions.—Trauma from a fall, vehicular or other type of accident, or from heavy lifting or a sudden twist (especially of the neck or lumbar spine) may result in a fracture or fracture-dislocation of one or more vertebrae, and perhaps in herniation of an intervertebral disk.^{43,44} Any of these conditions may lead to neurological disturbances from compression of the spinal cord⁷ or cauda equina, or to pain due to nerve root compression.⁴⁵

Violence transmitted to the spine with or without a fracture may result in spinal cord concussion, edema, contusion or hematomyelia, while

laceration of the cord or its nerve roots may be caused by a penetrating knife, ice-pick, or bullet wound, as well as by fragments of indriven bone.^{12,44}

The formation of a post-traumatic extradural cyst, apparently due to herniation of the arachnoid membrane, is a rare finding that may result in intermittent or progressive signs of spinal cord compression.^{25,32,51}

An acute traumatic episode, especially if accompanied by subarach-

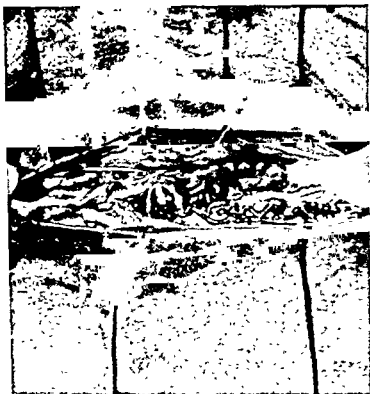


Fig. 178 —Operative exposure of angioma of spinal cord in region of conus medullaris. Note huge vascular channels at center of exposure. Signs and symptoms were extremely variable in this case, and commenced after spinal puncture for the administration of spinal anesthesia, one year prior to laminectomy. (Author's case; photograph by courtesy of E. Effron, M.D., New York, N. Y.)

noid bleeding, may eventuate in arachnoidal adhesions which in a severe form (regardless of cause) may so constrict the spinal cord and its blood vessels as to produce cavitation (syringomyelia).^{29,35} Spinal trauma apparently may sometimes accentuate signs or symptoms of multiple sclerosis or amyotrophic lateral sclerosis.

Finally, a discussion of trauma should include the occasional cases that suffer spinal cord changes as the result of spinal anesthesia.^{27,36,39} Such cases sometimes prove to have preexisting cord disease (Fig. 178).

Congenital Conditions.—Among the congenital conditions that may disturb the function of the spinal cord or cauda equina are meningoceles and meningomyeloceles^{8,26,40}; arachnoid cysts (Fig. 177)²⁵; dermoid and epidermoid tumors (the latter sometimes having an associated dermal sinus manifested by a draining dimple of the skin); and vascular anomalies^{9,13,55} such as varicose vessels, aneurysm^{15,48} or angiomas involving the spinal cord and nerve roots (Fig. 178). Angiomas may be extradural, intradural or both.

The congenital anomalies of the skeletal system most often seen include platybasia (basilar impression of the base of the skull)^{21,27,56} which may lead to spinal cord changes sometimes simulating multiple sclerosis; spina bifida²⁸ with an associated meningocele or arachnoidal cyst; and the Klippel-Feil syndrome.^{8,37}

Miscellaneous.—Degenerative diseases^{1,22,24,34,52} such as multiple sclerosis, amyotrophic lateral sclerosis and combined system disease; syringomyelia; thrombosis of the anterior spinal artery; virus diseases and neurosyphilis³³ must be considered in the diagnosis of spinal cord diseases.

DIFFERENTIAL DIAGNOSIS

History.—The first function of the history is to determine whether or not the disease process is neoplastic, inflammatory, post-traumatic, congenital or degenerative.

Loss of weight and other characteristics of a malignancy, together with a history of neurological disturbances of rapid progression, suggest a metastatic tumor of the spine. In contrast, slowly progressive symptoms insidious in onset, in an otherwise healthy individual, are often associated with a primary neoplasm within the spinal cord.

A history of tuberculosis, syphilis, gonorrhea, a virus disease or a focal infection may of course indicate an inflammatory or postinfectious disease of the spinal cord.

A history of pain accentuated by alterations in posture is characteristic of post-traumatic conditions such as herniation of an intervertebral disk or narrowing of an intervertebral foramen.

A history of disability from birth suggests a congenital lesion such as spina bifida associated with a meningocele, while symptoms of other congenital anomalies, whether vascular (angiomas) or skeletal (platybasia) may not come on until the second decade or later.

Degenerative diseases of the spinal cord are usually not accompanied by a history of pain, but have other well known characteristics. For example, *multiple sclerosis* is usually associated with signs of cranial nerve or cerebral involvement as well as with both sensory and motor changes of spinal cord origin, and is also characterized by remissions;

while *amyotrophic lateral sclerosis* is free of sensory disturbances and tends to run a progressive course without remissions. When a degenerative disease is suspected the history should rule out dietary deficiencies and also the possibility of syphilis which, though treated, may eventuate in a syndrome not unlike amyotrophic lateral sclerosis.

A second function of the history is to indicate the location of the lesion. Root pain indicates the level and the side of the lesion. The level may often be indicated by the distribution of numbness in trunk or extremities although this is not always a reliable guide, as a tumor may be several segments higher than the sensory level.¹⁶ Indeed, initial subjective sensory complaints indicating a spinal cord tumor may for months be so vague and intermittent that a diagnosis of hysteria or multiple sclerosis is made.

The patients should be asked whether the temperature of bath water feels different on opposite sides of the body, suggestive of a Brown-Séquard syndrome. If temperature perception is bilaterally impaired in a girdle zone over the trunk this is suggestive of syringomyelia. The patient should be asked whether he can walk without falling in the dark (a characteristic of *tabes dorsalis*, combined system disease, and sometimes of a cord tumor pressing on the posterior columns). Subjective *variability* of sensory modalities may be an indication of varicosities or an angioma of the spinal cord, due to variable distention of the abnormal blood vessels.

Motor.—A history of the mode of onset and course of motor disability helps determine the location and type of a spinal lesion. Thus, weakness of the legs but not the arms suggests a lesion below the cervical level affecting the lateral aspects of the cord, while impairment of bladder and rectal control as an initial symptom suggests a lesion affecting the ventral part of the cord, *conus medullaris*, or sacral roots.

Weakness of specific muscle groups furthermore may prove as accurate in localizing a lesion as sensory findings. The reader who wishes to refresh his memory on the innervation of individual muscles (and sensory distribution) is referred to the charts in Elsberg's book on spinal cord tumors.¹⁶

Most ruptured intervertebral disks result predominately in unilateral pain and neurological disability, although midline herniations of course lead to bilateral signs. In the neck the commonest sites for a herniated nucleus pulposus are between C 5-6 and C 6-7; in the lumbar region at L 5-S 1 or L 4-5 and more rarely at L 3-4 and L 2-3. Multiple herniations may also occur.³⁰

NEUROLOGICAL EXAMINATION

Examination of the patient should of course include a thorough physical examination with reference to the possibility of a malignant tumor,

enlargement of the lymph glands, pulmonary disease, deformity of the spine, and cutaneous anomalies such as pigmented areas (café-au-lait or melanotic spots); subcutaneous nodules (lipomas or neurofibromas); vascular nevi; dermal sinuses and so forth. Foci of infection should be looked for, including prostatitis, and the rectal tone should be checked.

Motor Status.—The gait, stance, and ability to move the trunk and extremities should be noted, while muscle strength and reflex status should be recorded. Fascicular or fibrillary muscle twitching should be sought for since they may be indicative of anterior horn cell disease or degeneration of nerves. Fasciculation may often be observed clinically at the level of a cord lesion and may be demonstrated by electromyograms.²³

Sensory Status.—All forms of sensation should be carefully tested, and the saddle area should not be overlooked. In general, nerve root involvement is indicated by sensory changes affecting all modalities; an intramedullary tumor or syringomyelia by a bilateral girdle-like band showing impaired pain and temperature perception (since these fibers are usually destroyed as they cross the anterior commissure of the cord); while impairment of posterior column sensation alone (vibration and position sense) may indicate either a tumor pressing on the dorsal aspect of the cord, a degenerative disease such as that associated with primary anemia, or tabes dorsalis, the latter usually being accompanied by lightning pains in addition.

The Brown-Séquard syndrome signifies disease or compression of one half the cord and is characterized by impaired pain and temperature perception on the side opposite the lesion, with impaired vibratory and position sensation, reduced power and abnormal reflexes on the same side.

Spotty, scattered sensory and motor findings usually point to a degenerative disease such as multiple sclerosis, or to adhesive arachnoiditis or varicosities.

When all sensory and motor function is lost below a given level it is of course obvious that a complete transverse lesion of the cord exists, a band of hyperesthesia being frequently found at the level of the lesion, just above the upper limits of sensory loss.

Autonomic Status.—Sometimes the level of a cord lesion is clinically demonstrable by altered skin temperature, sweating or pilomotor response, while a Horner's syndrome points to a cord lesion at C 8 - T 1.

X-RAY STUDIES

Aside from myelography (see below) x-rays are essential to determine the presence or absence of erosion of bone by neoplasm or osteo-

myelitis; evidence of widening of the interpedicular measurements suggestive of an intraspinal tumor;¹⁷ or congenital defects such as spina bifida, the Klippel-Feil syndrome, or platybasia (basilar impression). Hemangioma of the vertebra, multiple myelomas, bone tumors and the like can also be recognized by roentgenograms. Evidence of trauma such as a fracture, dislocation or narrowing of the intervertebral foramina and disk spaces may also be detectable. Calcification within an intraspinal tumor occasionally occurs, but is rare.

LABORATORY STUDIES

Routine laboratory investigation should include a complete blood count, urinalysis, blood serology and erythrocytic sedimentation rate. Special studies of the blood chemistry, a reticulocyte count, gastric acidity, and so on may be reserved for appropriate situations. Blood calcium, phosphorus and phosphatase determinations often prove valuable in the diagnosis of metastatic and other bone lesions, while disturbances of the serum albumin-globulin ratio and the presence of Bence-Jones protein in the urine usually indicates multiple myeloma. Microscopic examination of a biopsied lymph gland may reveal evidence of new growth in the lymphoid system.

Cerebrospinal Fluid.—A single lumbar puncture may serve three purposes: (1) a test of blockage within the spinal canal³¹; (2) a sample of cerebrospinal fluid for analysis; (3) a means of carrying out a myelogram.

1. As pointed out elsewhere,⁴⁴ greater accuracy in the manometric test can be achieved by using a water instead of a mercury manometer. Normal readings in water pressure range from 100 to 200 mm. Light, momentary bilateral jugular compression normally yields an immediate rise of 10 mm. or more, with a swift return to the initial pressure. Firm bilateral, simultaneous jugular compression for exactly ten seconds normally yields a sharp elevation of cerebrospinal fluid pressure which returns to the resting level within 20 seconds. Compression may be accomplished digitally or with a blood pressure cuff about the neck.²⁰

In the presence of partial block a slow rise and fall will occur while the pressure of the cerebrospinal fluid tends to remain higher than its initial level. A total block prevents a rise in pressure on jugular compression. It is helpful to time the rise and fall with a stop watch and chart the findings on a simple graph.

2. While xanthochromic cerebrospinal fluid may indicate subarachnoid bleeding of fairly recent origin secondary to trauma or rupture of a varicose vessel, it is more apt to be associated with a complete long-standing cerebrospinal fluid block. Fluid that clots on standing usually indicates a block in the lower thoracic or lumbar region.

The average normal value of total protein of the cerebrospinal fluid does not exceed 40 to 50 mg. per 100 cc. As a rough guide, the following



Fig 179—Pantopaque myelogram (6 cc) showing defect caused by herniation of the nucleus pulposus between C 6 and 7 on the right. A tumor outline is generally more regular and rounded. (Courtesy of E. H. Wood, M.D., Chief, X-ray Department, The Neurological Institute of New York.)

values associated with some of the commoner spinal cord lesions may be offered:

	Total Protein of Cerebrospinal Fluid (mg per 100 cc)
Arachnoid adhesions	35-50
Herniated nucleus pulposus.	55-75
Varicosities of spinal cord	65-85
Cord tumor (incomplete block)	85-100
Cord tumor (complete block)	100-2400

A mild degree of pleocytosis is usually associated with a virus disease of the central nervous system, but not with a neoplasm or herniated disk. In the virus diseases the total protein is generally not greatly elevated. The Guillain-Barre syndrome is characterized by a high protein and low cell count of the cerebrospinal fluid.⁴⁵ Marked pleocytosis or frankly turbid cerebrospinal fluid accompanies meningitis, the type

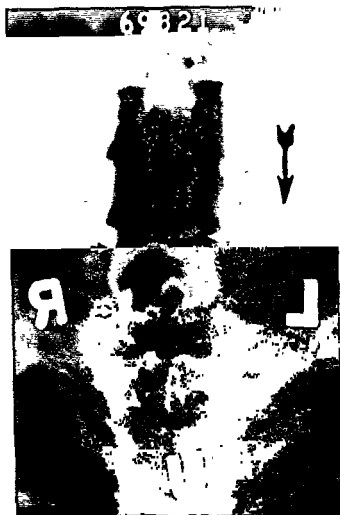


Fig. 180.—Circular defect indicates right ventral encapsulated neurofibroma at C 1-T 1. Four years history of pain in upper back. Paresthesias of hands and progressive weakness and stiffness of legs for fifteen months. Sensory level at T 2 prior to operation. Successful removal of tumor.

being determined by the clinical findings and other studies which should include a culture and smear of the cerebrospinal fluid. In tuberculous meningitis a low sugar content of the cerebrospinal fluid is a characteristic finding. Other tests of the cerebrospinal fluid include a Wassermann or the equivalent, and a colloidal gold curve.^{1,19,33}

3. Myelography.^{28,32} Myelography is best carried out with 6 cc. rather than 3 cc. of pantopaque dye, as the larger amount gives better visual-

Sensory impairment, and atrophy, weakness, hypoactive reflexes and fasciculation of the affected muscles help localize the lesion. Spinal cord compression by the disk may lead to weakness of one or both legs and abnormal neurological signs, including difficulty in micturition, below the level of the lesion.^{3,7,43}

X-rays usually show a narrow intervertebral space and reversal of the normal curvature at the affected site. Lumbar puncture may reveal a partial block and elevated protein of the cerebrospinal fluid, while myelography will usually disclose a characteristic defect (Fig. 179).

Although an anterior scalene syndrome may resemble a disk syndrome, the former can be ruled out by appropriate tests, and is usually automatically excluded if there are signs of spinal cord involvement. A diagnosis limited to hypertrophic osteoarthritis should not be made until the possibility of a ruptured disk has been ruled out.

Herniation of a lumbar disk should be looked for in cases suffering low backache with pain radiating down one or both sciatic nerves following a recent or remote back strain or injury. Such pain is usually accentuated by coughing, straining or change of posture. Other diagnostic clues include limitation of straight leg raising (with no discomfort on full flexion of the hip and knee joints); local spinal tenderness and sciatic nerve tenderness; paravertebral muscle spasm; and motor and sensory findings characteristic of nerve root compression. *Herniation between L 4-5* is frequently associated with greater difficulty in straightening up the spine; fewer sensory and reflex changes, and impairment of the posterior tibial reflex¹⁴ as compared with herniation at L 5 - S 1. The chief signs of the latter consist of considerable limitation of straight leg raising; impairment of the Achilles reflex; sensory impairment on the outer aspect of the foot and saddle area; and atrophy of the gluteal and peroneal muscles.

While x-rays frequently reveal narrowing of the intervertebral space at the affected level, myelography should be done whenever the diagnosis is in doubt, especially as disk protrusions may be multiple

* * *

In conclusion, the author urges that all cases in which a diagnosis of a degenerative disease of the spinal cord is suspected be thoroughly investigated with the aid of x-rays, cerebrospinal fluid studies and myelography, as many cases believed to be in this category subsequently prove to be cord tumor, a congenital defect of the spinal canal or foramen magnum, or a cervical disk lesion—conditions that can be helped by neurosurgery.

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SURGICAL MANAGEMENT OF TUBERCULOSIS

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SURGERY in the treatment of pulmonary tuberculosis occupies a unique position in the field of surgery, in that the surgery is not definitive but is merely an adjunct in the treatment of patients having this condition. It has long been recognized that surgery will not eradicate tuberculosis from the body. Arnold de Villanova¹ (1235-1312) stated, "In most cases of scrofula external applications are better than the use of the knife. Scrofulous patients always have other sources of infection within them." This aphorism laid down centuries ago is sometimes forgotten and often needs restatement. Sweet² in 1946, while discussing the reasons for failure in resection for pulmonary tuberculosis, made the statement that "tuberculosis is not primarily a surgical disease." Surgery in the treatment of pulmonary tuberculosis attains its results by an indirect method. Since pulmonary tuberculosis in the usual adult form tends to be a chronic disease owing to the fact that the tissues of the body continually make an attempt to contain and fibrose the infection, this natural healing process can be augmented by collapse or relaxation of the diseased portions of the lung and thus hasten and make more sure the final healing process. Permanent collapse also seems to protect the patient against future reactivation of the disease.

The scope of this paper will be confined to the broader aspects of surgical management of tuberculosis. The application of commonly accepted surgical procedures to this problem will be discussed. The indications for these procedures which are constantly changing will be presented in the light of present opinion.

Although surgery is considered only an adjunct of treatment it plays an important role in the management of patients having tuberculosis. Now tuberculous patients are considered for some type of collapse or surgery with the exception of those in whom the disease is so minimal that such treatment is not necessary or those patients in whom the disease is so far advanced that therapy of this type is impossible. In a recent survey at a small county sanatorium where a combined medical and surgical staff recommend procedures for patients under treatment, it was found that, of the ninety-three patients in the sanatorium, sixty had undergone some type of surgical procedure. Table 1 indicates frequency of procedures used and reasons contraindicating surgery. Leslie and

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Anderson⁴ showed the value of a collapse therapy program in a sanatorium. Comparing results in sanatoria where collapse therapy was extensively used with those where it was not, there were not only more patients discharged with a diagnosis of arrested disease but also fewer deaths. These fewer deaths occurred in the face of the accepted mortality of the various surgical procedures that were used.

TABLE 1

COLLAPSE THERAPY IN NINETY-THREE UNSELECTED TUBERCULOUS PATIENTS

No Collapse Therapy	33
Disease minimal	1
Disease too far advanced	28
Nontuberculous complications	3
Surgery refused	1
Collapse Therapy	60*
Diaphragmatic paralysis (with pneumoperitoneum, 5)	12
Pneumothorax-effective (attempted in 37)	17
Pneumonolysis	14
Thoracoplasty	29
Resection (lobectomy)	2

* Total number of procedures does not equal total patients because of patients having more than one type of collapse

GENERAL CONSIDERATIONS

Surgery in pulmonary tuberculosis is designed to augment the healing process. This may be through relaxation of the diseased tissue, through collapse, through drainage, or through actual resection of the major focus. Relaxation may be all that is necessary to bring about complete healing of a new exudative lesion or a flare-up around a previously healed lesion. More chronic cavernous areas may need to be collapsed. Along with this collapse there may be a measure of compression. Clinical observation has shown that collapse is good for a tuberculous lesion while overdistention tends to cause reactivation. This reactivation with overdistention has been one of the pitfalls in the application of pulmonary resection to this problem.

Cavity closure and resultant sputum conversion is the criterion of success in the treatment of pulmonary tuberculosis. In using this criterion of success one does not overlook, however, such important factors as the general nutrition of the patient and the eradication of all signs of activity and the disease. Cavity closure may be influenced by many important

mechanical factors. Tuberculous tracheobronchitis is perhaps the most important factor operating within the lung which influences the closure of cavities. Obstruction of the bronchial lumen by ulcerating tissue and bronchial secretion may cause a valvelike action which places cavity areas under positive pressure. Such cavities resist closure and unless this mechanical factor can be eradicated it may be difficult to gain a good result. The thickness of the wall of a cavity may be so great that closure would be impossible by collapse. In these tuberculoma-like cavities nothing except excision will aid the patient in regaining his health. The extent of the pericavernous tissue may also influence the time factor in bringing about complete cavity closure so that one would have to wait a much longer period following collapse for sputum conversion than in patients having cavities with thinner walls. In old cavities there may be epithelialization of the interior of the cavity from the bronchial mucosa. This will make impossible complete healing of the cavity. Cavities low in the lung and cavities near the mediastinum may be extremely difficult to close by any method.

There are general considerations that must be borne in mind in selecting the correct type of therapy. The extent of the disease within the lung influences decisions made. The disease may be so minimal that surgery would not have to be contemplated, or the extent of the disease may be so great that surgery is inadvisable since there would be insufficient pulmonary tissue to support life after the surgical program had been completed. Between these two extremes, however, there exists a group of patients who have disease of various extent—usually bilateral although often the disease is predominantly in one lung—who are suitable for the surgical procedures that have been devised for the treatment of this disease. The general advance of the disease or deterioration in the condition of the patient may contraindicate or be cause for abandoning collapse therapy. Whether the disease is exudative or fibroplastic in its nature becomes an important consideration in the selection of therapy.

The age of the patient must be considered. Thoracoplasty is a badly deforming operation on individuals in the growth period and thus should not be used in these patients. Advanced age may not absolutely contraindicate certain of the major surgical procedures but might make them inadvisable. The estimated immunological response of the patient to the disease must be evaluated. Pulmonary tuberculosis is a disease given to exacerbation and remission. The timing of the application of the various surgical procedures must be carefully considered in order to attempt to carry out the procedure at a time when the patient is in the best possible condition. Rest and chemotherapy may do a great deal to bring a patient into a condition where a procedure can be safely used. The patient's economic situation must also be considered. Some types of therapy must

be carried on over a period of months and years and may entail considerable expense. Very often the choice between two procedures, both of which stand a good chance of success, may be made purely on the economic basis.

The temperament of the patient and his ability to cooperate may influence decision as to therapy. Some types of treatment, notably pneumothorax, require the utmost in cooperation between the patient and the physician. There are some people who are not temperamentally suited for a drawn-out period of treatment which requires such self-discipline. In patients of this temperament a permanent type of collapse such as thoracoplasty may be preferable.

PNEUMOTHORAX

Pneumothorax in suitable patients and properly administered is ideal treatment. Unfortunately it is applicable to only approximately 20 per

TABLE 2

CONTRAINDICATIONS TO PNEUMOTHORAX

1. Pleural symphysis
2. Tuberculous pneumonia and acute exudative lesions
3. Tuberculous bronchitis with signs of bronchial obstruction.
4. Extensive pulmonary destruction
5. Tension or balloon cavities
6. Tuberculomas or tuberculoma-like cavities
7. Acute pleurisy with effusion.
8. Dyspnea due to emphysema or cardiac disorders.

cent of tuberculous patients. The hoped-for result with pneumothorax is selective collapse of the diseased area and partial functioning of the undiseased portion of the lung. This collapse is then maintained over a period of years during much of which time the patient is carrying on his normal pursuits. As soon as it is considered that the lesion is firmly healed the lung is slowly re-expanded. One must not forget that although pneumothorax seems to be a minor procedure it is not without danger. Salkin and Cadden,² in a carefully studied series of pneumothorax patients, reported that the mortality of pneumothorax therapy was 3 per cent. This was the mortality of the procedure itself and did not count the mortality of its major complication, empyema. The argument, therefore, in favor of pneumothorax must be based not on the matter of safety but upon the basis of preservation of pulmonary function and the avoidance of deformity of the chest. The contraindications for pneumothorax are listed in Table 2.

The evaluation as to whether a pneumothorax is going to be effective or not should be made as soon as possible after the initial puncture to

save time and avoid complications. Unless a pneumothorax can be rendered free of all adhesions, the pneumothorax is not likely to be successful and should be re-expanded. The physician should not be misled by mere improvement following a measure of collapse by pneumothorax. Unless the cavities are actually closed and the sputum is converted nothing of actual value has been accomplished. Pneumothorax has little or no place in the role of preparing a lung for a subsequent procedure. Table 3 lists the indications for re-expanding unsuccessful pneumothoraces.

Pneumonolysis which is a corollary operation to pneumothorax is a safe procedure as long as the operating surgeon exercises good judgment.

TABLE 3

INDICATIONS FOR RE-EXPANSION OF UNSUCCESSFUL PNEUMOTHORACES

1. Pleural adhesions that cannot be safely cut.
2. Persistent pleural effusion.
3. Cavities—enlarging or persistent.
4. Atelectasis of underlying pulmonary tissue
5. Dyspnea.
6. Recurring spontaneous collapses.
7. Thoracoscopic discovery of subpleural tubercles.

TABLE 4

COMPLICATIONS OF PNEUMOTHORAX

1. Empyema.
2. Air embolism.
3. Spontaneous pneumothorax
4. Unexpandable lung
5. Obliterative pleuritis

The ideal time to cut adhesions is as soon as there is a sufficient pneumothorax space in which to work. The mortality of this procedure is less than 1 per cent. The risking of pleural complications will depend a great deal upon what other measures are available to the patient. The surgeon has no right to take a great risk of obtaining an empyema in a patient on whom a thoracoplasty can be done

DIAPHRAGMATIC PARALYSIS

The value of diaphragmatic paralysis in the treatment of tuberculosis has been under discussion for many years. In some clinics a high percentage of patients receive this type of therapy while in others it is scarcely used at all. This extreme variation in the opinion of various men in respect to this procedure shows that at best the results are unpredictable. It seems fair to state that mere relaxation of the diaphragm could not be expected to yield a great influence upon lesions within the lung.

TABLE 6
RESULTS OF THORACOPLASTY IN 169 PATIENTS, 1946-1947
(Shaw and Paulson)

Total No.	Satisfactory	Unsatisfactory	Mortality
169	137 (81%)	24 (14.3%)	8 (4.7%)

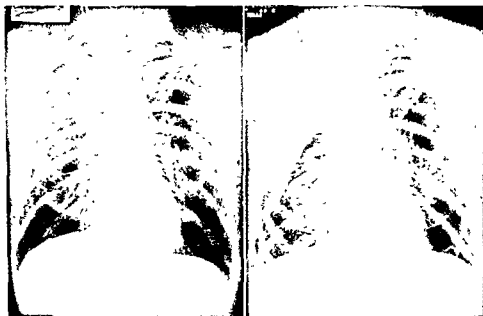


Fig 182.—Six rib thoracoplasty with scapulectomy giving selective collapse with maximum preservation of pulmonary function



Fig 183.—Destroyed lung collapsed with a nine rib thoracoplasty. Sputum conversion was obtained three months following the third stage

On the other hand the addition of this therapy may be enough to allow a lesion to heal which would not heal without this aid. Diaphragmatic paralysis as a preparatory measure is usually not advisable because of the danger of losing valuable respiratory reserve. Diaphragmatic paralysis should seldom be made permanent since permanent loss of diaphragmatic function with no assurance of success is a gamble that is not worth taking. With proper understanding of the anatomy of the phrenic nerve and its accessory nerves it can be temporarily interrupted in such a way that function should return in all but a small percentage of patients within six to eight months. If it is advisable to continue the diaphragmatic paralysis beyond that time the operation can be repeated. The usual indications for diaphragmatic paralysis are found in Table 5.

PNEUMOPERITONEUM

Pneumoperitoneum is used enthusiastically in a few clinics, with septicism in some, and in others not at all. In conjunction with di-

TABLE 5

INDICATIONS FOR DIAPHRAGMATIC PARALYSIS

- 1 Minimal lesions—to augment bed rest
- 2 Cavities less than 3 cm. in diameter when pneumothorax has failed
- 3 Supplementary to a re-expanding pneumothorax.
- 4 Basal lesions beneath an upper thoracoplasty.
- 5 Noncavernous flare-up around old fibrotic lesions
- 6 Following resection

aphragmatic paralysis it seems to have a place in the treatment of bilateral disease when no other procedures are immediately feasible. The relaxation it affords by elevating the diaphragm may favorably influence the course of the disease so that more definitive procedures can be used later. Its use should be discontinued if significant ascites occurs or if the patient finds it seriously interferes with eating. Serious complications with this therapy are rare and it can be easily discontinued.

THORACOPLASTY

Thoracoplasty has proved to be one of the most successful procedures in the surgical treatment of patients having pulmonary tuberculosis. The technic of this operation has been greatly refined so that the accepted mortality is now less than 3 per cent and the good results that can be expected are in the neighborhood of 80 to 90 per cent (Table 6). This lowering of the mortality and increase in good results obtained has been accomplished in face of the fact that patients presenting much poorer risks are now being accepted for this procedure. The performing of the

Thoracoplasty is indicated in patients having cavernous disease in one lung in which the other lung is free of disease or at least quiescent. Tuberculous tracheobronchitis may mitigate against a good result in thoracoplasty but does not necessarily contraindicate it. Thoracoplasty is either contraindicated or cannot be expected to succeed in situations recorded in Table 8. By far the most common contraindication to thoracoplasty is lack of respiratory reserve. Obviously one cannot collapse a lung which is bearing some of the share of respiration in a patient who is already dyspneic. Before a patient is accepted for thoracoplasty he must be carefully evaluated from the standpoint of respiratory reserve to make sure that he can tolerate the full program contemplated. It is an injustice to the patient to start a procedure if it stands very little chance of being successfully completed.

EXTRAPLEURAL OPERATIONS

The necessity of staging thoracoplasties and the resulting deformity caused by thoracoplasty has led to a continuing search for an operation which will yield as good results without these disadvantages. Various operations creating collapse by separating the parietal pleura from the endothoracic fascia have been devised. The maintenance of this space has been accomplished by the use of a variety of space-filling material; i.e., air, oil, paraffin, fat, muscle and plastic balls. Regardless of the type of material that is used to fill the created extrapleural space, all of these operations suffer certain disadvantages as compared to thoracoplasty. They are not safe over large cavities where the lateral wall of the cavity may be receiving some of its blood supply from the intercostal vessels. In these patients rupture of the cavity into the extrapleural space is not uncommon and yields a severe complication. The creation of a space within the body invites complications and is undesirable regardless of the material used to fill the space. Frequently a thick-walled cavity may be displaced downward by the extrapleural operation without closing it, which leaves an almost impossible therapeutic problem.

Enthusiasm for the extrapleural operations has waxed and waned. In the hands of most surgeons these operations are used in a limited number of indications where maximum preservation of vital capacity is necessary in order to use another procedure to control lesions in the opposite lung (Fig. 184). Limited extrapleural separation with the use of oleothorax or paraffin is very successful in small honeycombed lesions at the extreme apex of a lung. As a procedure by itself it should not supplant thoraco-



Fig 184—Extrapleural pneumothorax converted to oleothorax, on the right, combined with a seven rib thoracoplasty on the left to close bilateral apical cavities

plasty but it may be exceptionally useful to aid in arresting disease in a small group of patients with bilateral lesions.

PULMONARY RESECTION

Improvement in the technic of pulmonary resection has naturally encouraged surgeons to apply this procedure to the problem of pulmonary

TABLE 9

RESULTS OF PULMONARY RESECTION FOR TUBERCULOSIS IN TWENTY-TWO PATIENTS
(Shaw and Paulson)

Indication	Total No.	Satisfactory	Unsatisfactory	Questionable	Died
Stricture.....	4	1		3	0
Bronchiectasis....	4	3		1	0
Bronchial granuloma....	1		1		0
Inadvertent.....	3	1		1	1
Tension cavities	3	1		1	1 (late)
Total.....	15	6	1	6	2
Tuberculoma.....	7	7	0	0	0

TABLE 10

RESECTION IN PULMONARY TUBERCULOSIS

Accepted Indications

1. Bronchial stenosis blocking drainage of lung.
2. Bronchiectasis.
3. Cavities in lower lobe with other lobes relatively clear.
4. Thoracoplasty failures.
5. Tuberculomas and tuberculoma-like cavities.
6. Severe hemoptyses uncontrolled by other measures.
7. Epithelialized cavities.

Questioned Indications

1. Destroyed lobes or lungs.
2. Tension cavities.
3. Empyema over a destroyed lung (resection combined with pleurectomy).

tuberculosis. It is highly tempting to resect the major focus, thus quickly converting the sputum and rapidly improving the situation of the patient in one operative procedure. The immediate mortality in resection for pulmonary tuberculosis is now less than 10 per cent (Table 9). Unfortunately the late results of lobectomy and pneumonectomy for pulmonary tuberculosis have been disappointing. Although the patient may be greatly improved immediately following the procedure there is a tendency for other lesions within the lungs to break down later.

advisable but may be indicated to (1) remove fibrin clots that cannot be aspirated (2) obliterate small persistent pockets.

Decortication of the lung carried out with meticulous technic and aided by streptomycin therapy can now be safely applied to the problem of tuberculous empyema. The choice between thoracoplasty and decortication depends chiefly upon the estimated condition of the underlying lung. If cavities persist or the lung had been largely destroyed by the disease, thoracoplasty is preferable. A lung imprisoned by an empyema which complicated a pneumothorax carried out for minimal or moderately advanced disease may be re-expanded by decortication (Fig. 186). A combination of the two procedures can be effectively used employing a



Fig 186—Re-expansion by decortication of a lung collapsed by a tuberculous empyema. The empyema complicated a therapeutic pneumothorax instituted eight and one-half years before.

thoracoplasty to close residual cavities in the upper lobe and later doing a decortication of the lower lobe to obliterate the remaining empyema space. With decortication in addition to obliterating the infected pleural cavity it is hoped there will be some return of pulmonary function. Recent studies by Wright⁶ show that return of function may be disappointing in that although the lung is aerated and there is some increase in the breathing capacity there may be an increase in desaturation of the arterial blood with oxygen since a pulmonary arteriovenous shunt is obtained by opening vascular channels in a fibrotic lung. This should not mitigate against the use of decortication, however, since the gain to the patient of being rid of the infected pleural space is of greatest importance.

Some surgeons are employing pleurectomy combined with total pneumonectomy to eradicate an empyema over a destroyed lung.

An unroofing procedure of a modified Schede type will be necessary to obliterate many empyemas that cannot be successfully obliterated by extrapleural thoracoplasty or decortication. Preservation of the intercostal muscles and periosteum after removal of the overlying ribs and parietal pleural scar as advocated by Grow affords foci of granulating tissue which will aid to obliterate the space and to stiffen the chest wall. Approximation of the muscles of the chest and the subcutaneous tissue loosely about several soft rubber drains will make packing of the wound unnecessary, save the patient much discomfort, and hasten eventual healing of the wound.

BRONCHOSCOPY

Bronchoscopy has become indispensable in the surgical management of pulmonary tuberculosis. Bronchoscopy should be done if significant tuberculous bronchitis is suggested by symptoms or x-ray appearance of the lungs. It should be done routinely before instituting pneumothorax therapy, since this therapy is contraindicated in the face of significant bronchial disease. During streptomycin therapy for bronchial disease check-up bronchoscopies should be done by the same observer at two week intervals. Application of 30 per cent silver nitrate to ulcerating or granulomatous lesions can be carried out if indicated. In the presence of bronchial disease or copious sputum bronchoscopy should be carried out following each thoracoplasty stage while the patient is still anesthetized. Aspiration of secretions, dilatation of stenotic bronchi, and catheterization of bronchi draining blocked cavities should be done at this time. This will greatly enhance the obtaining of cavity closure, smoothe the postoperative course, and tend to prevent aspirational spreads. Severe tuberculous laryngitis is the only contraindication to bronchoscopy in the management of these patients. The presence of a stenotic larynx in a patient needing thoracoplasty or resection is an indication for preliminary tracheotomy so that a ready avenue is available for aspiration of secretions and carrying out intrabronchial therapy.

STREPTOMYCIN

Streptomycin has not altered the indications for the various procedures used in the surgical management of tuberculosis. It has, however, made possible the use of these procedures in many patients who would not have been suitable for them prior to its use. It has its greatest usefulness in acute exudative and bronchial disease. It has also made resection and decortication of tuberculous lungs much safer by preventing spreads and pleural infections. Streptomycin therapy should be carefully integrat-

with the surgical program so that the procedure used will be carried out at the optimum time. The value of the chemotherapy may be lost if the tubercle bacillus becomes streptomycin-resistant before necessary surgical procedures can be instituted. Streptomycin therapy employing 0.5 gm. twice daily should be used for two weeks prior to and at least two months after a resection or decortication for pulmonary tuberculosis. In many patients having unstable disease, streptomycin therapy should be used before and during thoracoplasty.

POSTOPERATIVE CARE

Maintenance of an open bronchial airway is the most important consideration of the postoperative care. If the patient cannot effectively cough out the bronchial secretions they should be suctioned out by use of an intrabronchial catheter or through a bronchoscope. Collections of fluid in the subscapular space that are threatening to drain through the incision following thoracoplasty should be aspirated through a needle. Thoracoplasty incisions should not be opened except to evacuate frankly purulent fluids. Following major thoracic operations early ambulation is desirable. The patient should be out of bed the day following surgery. The diet can be resumed as soon as the patient can tolerate it. Narcotics should be used judiciously. By the third or fourth postoperative day the average patient can be kept comfortable with $\frac{1}{4}$ grain of codeine and 5 grains of aspirin. The arm on the operated side must be put through a full range of motion the day after surgical intervention and this must be repeated frequently during convalescence. The patient should be reminded of faults in posture and instructed as to how to correct them.

PLANNING THE SURGICAL ATTACK

In planning the surgical attack in any specific patient the first questions that must be answered are (1) Is the program feasible? (2) What end result can be expected? The selection of patients suitable for surgery should be made with the implications of the full surgical program required in mind. Blundering into a complicated surgical program out of sympathy for the plight of the patient usually leads to regret. Patients rejected because of disease too far advanced or acute, or because of important extrapulmonary disease are not necessarily doomed. Prolonged bed rest, streptomycin, and correction of other disorders may make surgical attack feasible at another time.

It is sometimes difficult with bilateral disease to decide which side to attack first. It is good wisdom to collapse first the side with the major involvement since in many cases control of the major lesion will favorably influence the healing of contralateral lesions. A decade ago it was

considered heresy to start a thoracoplasty over one lung in the face of open cavities in the other. Alexander⁷ feels that thoracoplasty should be undertaken in the face of contralateral cavitation as long as the disease is relatively stable and procedures are available for the remaining disease should they be required.

Experience now allows one to estimate fairly accurately what procedures are likely to succeed in a given patient. The concept of trying lesser procedures to see if they will work before carrying out major collapse has been discarded. This has not only saved valuable time for the patient but has increased the percentage of arrested cases in the over-all group. It is justifiable, however, to use phrenic surgery, contralateral pneumothorax, and pneumoperitoneum as adjuncts to rest and chemotherapy to prepare patients for more definitive major surgical procedures. Many patients are now having so-called "primary thoracoplasties" and pulmonary resections when it is obvious that these procedures are the only ones that will adequately bring about arrest of the disease.

EVALUATION OF RESULTS

Evaluation of results is determined by the number of living patients and by conversion of sputum. Such important factors as respiratory function, general well-being, and rehabilitation are important but do not lend themselves well to statistical analysis. Experience has shown that a persistently positive sputum is a great hazard to an individual. The use of refined technics such as culture of gastric secretions has lowered the percentage of absolute sputum conversions usually recorded when negative concentrate sputum examinations were used as a criterion of conversion. Many men have questioned the danger of positive gastric cultures in the face of otherwise negative sputum tests. Certainly, an individual who has only an occasional positive gastric culture does not represent a public health hazard. However, it has been shown that he does run six times as much danger of a subsequent flare-up as an individual with negative gastric cultures. In a few patients the point is reached where only positive gastric cultures remain as evidence of active disease and a major surgical procedure would be required to effect final conversion. The hazard of the surgery and the resultant loss of pulmonary function in these patients must be weighed against the inherent hazard of the remaining disease. Often it is wise to "call quits" and leave "well enough" alone.

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with the surgical program so that the procedure used will be carried out at the optimum time. The value of the chemotherapy may be lost if the tubercle bacillus becomes streptomycin-resistant before necessary surgical procedures can be instituted. Streptomycin therapy employing 0.5 gm. twice daily should be used for two weeks prior to and at least two months after a resection or decortication for pulmonary tuberculosis. In many patients having unstable disease, streptomycin therapy should be used before and during thoracoplasty.

POSTOPERATIVE CARE

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MODERN TECHNICS IN THORACIC SURGERY

J. MAXWELL CHAMBERLAIN, M.D., F.A.C.S.* AND
JAMES J. FINNERTY, M.D.†

TECHNICAL aspects of thoracic surgery cannot be completely divorced from the principles which gave rise to them. The emphasis, however, in this review is on technics, or the surgical plan. Some of the more important technics are outlined and these are briefly described. Though we have had experience with most of the procedures outlined below, we have been the originators of none of them.

DECORTICATION TECHNIC

The essential points of technic are: (1) a careful, meticulous removal of the "peel" or capsule from the visceral pleura to prevent or reduce the number of alveolar "leaks"; (2) to remove especially the diaphragmatic element of the capsule and perhaps the costal element in order that diaphragmatic motion and costal breathing are re-established; and (3) to maintain *active* suction especially if there are one or more alveolar fistulas. The water-seal method of pleural decompression is a passive attitude toward the maintenance of re-expansion and though in wartime at forward echelons it is the more practical solution, in a modern surgical environment a successful result is best assured by active and immediate intrapleural suction. Regardless of the number of small alveolar fistulas it is possible to remove air at a rate sufficient to maintain a negative intrapleural pressure of 8 to 15 cm. of water. By this method the lung is intimately in contact with the chest wall which helps to seal the small leaking fistulas.

DRAINAGE TECHNIC IN LUNG ABSCESS

Chemotherapy has reduced considerably the need for surgical drainage of a lung abscess, but there will always be the negligent patient who consults the physician only after his abscess has reached a subacute or chronic stage. When drainage is considered preferable to resection the technical aspect of *where* and *how* to drain may be of great importance.

A pulmonary abscess may be thought of as a furuncle of the lung—a

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single necrotic focus which "points." Almost all lung abscesses in the process of "pointing" develop pleural adhesions. Drainage should occur through this area. It is analogous to the white bloodless area of a pimple or a large furuncle.

Surrounding the white bloodless area is a red inflammatory zone—the "front"—where the *invasive organisms combat the defensive mechanisms* of the body. In draining a simple furuncle we learned as a basic

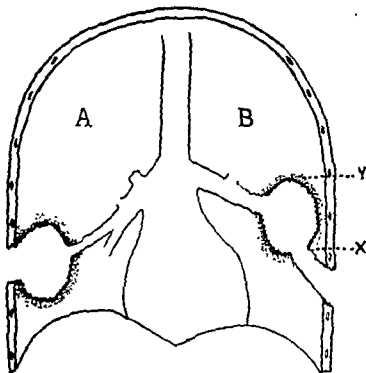


Fig 187 —Drainage technic in abscess of lung. A, Correct drainage, B, incorrect drainage; X, normal lung, Y, defensive inflammatory ring

principle never to carry the incision beyond this defensive inflammatory zone, but to drain through the necrotic center. This principle is equally true if a lung abscess is to be drained. To set up artificial adhesions at the first stage of an operation and at a second stage proceed to drain the necrotic center of the furuncle by crossing first the normal lung and then the "defensive ring," is to violate the first principle of surgical drainage (Fig. 187). It is in this way that daughter abscesses develop in the defenseless normal lung along the course of the drainage tract.

Further, we know that from a pathological viewpoint an inflammatory thrombosis of the small pulmonary veins occurs in the "defensive ring" of any furuncle. Were this not true every lung abscess should develop a

septicemia or metastatic brain abscesses. To create artificial adhesions and drain a pulmonary abscess through a tongue of normal lung (Fig. 187) in which there are pulmonary veins under negative pressure is to invite a septicemia or metastatic brain abscess.

Therefore, if at the time of drainage one discovers no fusion of the pleurae it is quite probable that the abscess is "pointing" in a near-by area. It is advisable from a technical aspect then to open the pleura and feel for the adhesions. Once located—and they are always or almost always near-by—a catheter may be placed in the pleural cavity and the wound closed. Suction upon the catheter will re-expand the lung and abolish the small pneumothorax present. In the proper location a new incision is made and drainage established through the comparatively ischemic area.*

SURGICAL TECHNIC IN TUBERCULOSIS

Technics in the surgical treatment of tuberculosis vary with the basic principles of therapy. These principles and typical examples are: (1) drainage (Monaldi); (2) relaxation (pneumothorax); (3) compression (extrapleural pneumothorax); (4) resection (lobectomy; pneumonectomy); (5) immobilization (phrenicectomy and intercostal neurectomy); (6) bronchial occlusion, and (7) circulatory alteration (both still experimental).

Drainage (decompression) is used in two ways: (a) open drainage and (b) closed drainage (Monaldi procedure). The technical points of significance in open drainage of a tuberculous abscess are the same as those outlined above in the section on lung abscess.

The Monaldi procedure finds its greatest usefulness in combination with a thoracoplasty. At the first stage, through an incision lateral to the pectoral muscles, anterior segments of ribs 1-2-3 and cartilages of 1-2 are resected. Since this is to be the drainage site of a later stage it is imperative to determine that the pleurae are fused in this area. If they are fused the development of an empyema is avoided. To be sure of this fusion the pleurae are examined by elevating the first intercostal muscle in the extrapleural plane. The fused area is then outlined with metal

* If the operation is being conducted under local anesthesia all sutures should be placed in the muscles for rapid closure before the pleural cavity is opened. The patient is then instructed to take in a large breath and hold it. The pleura is then quickly opened, a finger introduced and the adhesions located. During exploration with the pleural opening plugged by the exploring finger the patient is allowed to breathe. Only a small amount of air will enter the pleural cavity. Prior to withdrawing the finger the patient is again asked to take in a large breath and hold it. A catheter is rapidly introduced and traction upon the previously placed sutures closes the wound immediately. The small pneumothorax is abolished by suction upon the catheter as it is removed.

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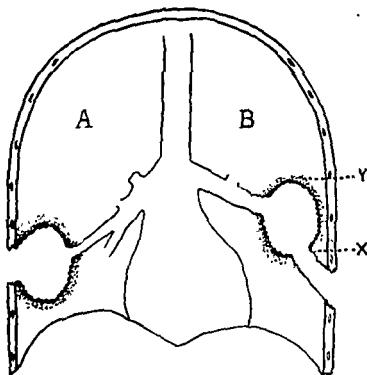


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Further, we know that from a pathological viewpoint an inflammatory thrombosis of the small pulmonary veins occurs in the "defensive ring" of any furuncle. Were this not true every lung abscess should develop a

as the desired collapse pattern is established. The thoracoplasty is done one month to six weeks later.

The axillary or posterior approaches are better than the anterior in extrapleural pneumothorax since the greatest difficulties are encountered in the vertebral gutter. Two points of technic may be emphasized. First, a meticulous airtight closure should be obtained, and second, the dissection must proceed up over the apex of the lung and downward along the mediastinum well toward the hilum of the lung. The resulting collapse is horizontal and is less likely to re-expand. Extrapleural pneumothorax is rarely used as a reversible procedure. A small anterior catheter may be left in place for forty-eight hours, to facilitate the regulation of pressure. Through the catheter the clots and serosanguinous material may be replaced with saline and 400,000 units of penicillin on the first postoperative day and air used to replace the saline on the second postoperative day.

Resection, one of the oldest principles of surgical therapy, can hope to remove only the major focus. Residual foci are always left behind, but it is hoped that these are healed and will remain so.

The technical feat of greatest importance in resection of a segment, a lobe or a lung is the skill with which the surgeon reaches and occludes the bronchus draining the offending focus. Each surgeon must develop his own style in this respect, but a few basic principles may be mentioned. The surgeon should avoid manipulating, compressing or pushing against the diseased area any more than is absolutely necessary before isolating and occluding the significant bronchus. Division of adhesions and mobilization of the lobe or lung must be reduced to the minimum until the bronchus is occluded. The bronchial component of the hilum is best reached by a posterolateral incision with resection of the fifth rib for upper lobectomies and pneumonectomies and the sixth rib for lower lobectomies. The technic for rapid occlusion of the left upper lobe bronchus and the right lower lobe bronchus is described because these are reached with greatest difficulty.

To resect the left upper lobe the pleural space is entered, the rib spreader introduced and only adhesions in the vertebral gutter are divided with mobilization of the lung also limited to this area. The pleura over the pulmonary artery is divided near the apex of the lower lobe and two arteries ligated and divided. These vessels are those to the lingula and posterolateral segments of the lobe. The bronchus lies medial and slightly in front of these two vessels, but often is concealed by a large lymph gland which acts as a landmark and denotes the point of bronchial bifurcation. The gland may be removed if necessary and the bronchus isolated and occluded. The lobe is then mobilized, and the hilar dissection completed.

The right lower lobe bronchus is easily and quickly located, but the position of the middle lobe bronchus cannot be determined from the posterior approach, yet its position must be known before the lower lobe bronchus is occluded. To do this the dorsal bronchus to the lower lobe is identified, isolated, occluded and divided between small right angle clamps. By applying traction on the distal bronchial clamp the artery and vein to this segment are easily identified, isolated, ligated and divided. The middle lobe bronchus is easily seen on the opposite anterior wall of the parent bronchus. The lower lobe bronchus is then safely occluded below it. Mobilization of the lower lobe and the hilar dissection is completed in the standard way.

The technic of bronchial closure is not elaborate. Two traction sutures are placed proximal to the small right angle clamp used to occlude the bronchus. The bronchus is divided with a knife just proximal to the clamp and a small curved suction tip introduced into the bronchial lumen and all secretions in the tracheobronchial tree aspirated. Four to six vertical interrupted cotton or silk sutures are used to close the bronchial stump. In this way the floor of the bronchus molds itself to fit the horseshoe-shaped cartilaginous element. The final step and probably an important one is plenization of the stump.

Immobilization of the lung by intercostal neurectomy, phrenicectomy and scalenotomy is a technical procedure no longer in use. The principle of rest is sound, but the same result now is accomplished in other ways (thoracoplasty) without the undesirable side reactions (abdominal hernia, hypesthesia, numbness and the like).

Artificial Occlusion of the Bronchus and Ligation of the Vessels are two more principles in surgical therapy which are still in the experimental stage. Most of the work has been done upon animals. At the present time they are significant only as accidental occurrences in conjunction with other forms of therapy such as the thoracoplasty (*q. r.*).

THORACOPLASTY TECHNIQS

The modern selective thoracoplasty is our most successful surgical procedure, because it incorporates many of the basic principles outlined above. *Relaxation* is obtained if the thoracoplasty is performed before the elastic recoil of the lung has been neutralized by replacement fibrosis. *Compression* is secured, first, by the collection of subscapular fluid and air and later by the weight of the upper extremity as the scapula falls in. *Immobility* in the diseased area is achieved as soon as rib regeneration is complete and finally, *bronchial occlusion* (foreshortening, kinking, and so forth) together with *circulatory* alterations, though not well understood, nevertheless contribute their bit to the desired result.

There are many different thoracoplasty types, but the objectives which

each hopes to accomplish are: (1) to obtain maximum collapse; (2) to preserve respiratory function; (3) to minimize deformity; and (4) to retain a useful upper extremity.

Maximum collapse is obtained by (1) resorting to surgical collapse early while the elastic recoil of the lung is still present; (2) meticulous detachment of all muscles inserting into the periosteum of the operative area (the anterior serratus, the pectoralis minor, the posterior superior serratus, the posterior scalenus and the sacrospinalis group); (3) mobilization of the lung in the vertebral gutter which is accomplished incidentally in removal of the transverse processes or disarticulation of the ribs; (4) adequate removal of ribs (number and length); (5) release of the apex (Semb apicolysis) in cavities high in the vault and widely adherent to the mediastinum; (6) scapulectomy in "short" thoracoplasties (five to six ribs) to prevent re-expansion as the subscapular fluid is absorbed; (7) closure of the wound without drainage so that the subscapular fluid and air may compress the lung.

Respiratory function is preserved by (1) resorting to surgical collapse sufficiently early to prevent the development of overdistention emphysema in healthy lobes or segments as they compensate for the contraction of healing foci; (2) adequate but not excessive rib removal (partial scapulectomy rather than two or three unnecessary ribs); (3) meticulous surgery to prevent tearing the pleura which might result in a severe pleurisy and fixation of the diaphragm; (4) decortication procedures in combination with a thoracoplasty (see tuberculous empyema); and (5) avoidance of spreads by preservation of an effective cough mechanism.

Deformities are minimized by (1) resorting to surgical collapse at a time when only a "short" thoracoplasty (five to six ribs) is necessary to control the disease; (2) resection of scapula when catching on the last unresected rib; (3) preserving the attachments of the middle and anterior scaleni muscles to the periosteum of the 1st rib (cervical scoliosis); (4) preservation of the long thoracic nerve (winged scapula); and (5) good postoperative care (physiotherapy and so forth).

Useful upper extremities are best retained by (1) muscle-splitting operations; (2) good postoperative care (early exercise and the like); (3) visualization of the brachial plexus during removal of the 1st rib; (4) perfect anatomical closure of the wound; and (5) meticulous attention to the position of the long thoracic nerve.

THORACOPLASTY TYPES

The *modern selective thoracoplasty* (from above downward), with or without a Semb apicolysis and with or without removal of the transverse processes, is the most popular thoracoplasty type. It has two weaknesses; (1) the cough mechanism is badly crippled by the paradoxical chest anteriorly; and (2) the cavity

may "drop" in the thorax after the first stage, necessitating the resection of more ribs than was originally estimated.

The *modern selective thoracoplasty* (from below upward) has been revived by Dr Walter Fisher. It is the same operation, but done from below upward in order to establish the size of the collapse before the cavity has had a chance to "drop" in the thorax.

The *preparatory thoracoplasty* (Sauerbruch, modified) consists of the removal of short segments of the first five or six ribs in the vertebral gutter as a preparatory procedure for more definitive forms of therapy. It will markedly reduce the amount of sputum so that a lobectomy or pneumonectomy may be done with greater safety later. In some cases it may be preferable to follow it with a modern selective thoracoplasty or a revision procedure. It is not shocking, does not cripple the patient's ability to cough, but the collapse is poor.

The *P A P thoracoplasty* (posterior stage, anterior stage, posterior stage) is again being revived. The first stage is a modified Sauerbruch. All of the 1st rib and short segments of ribs 2-3-4 are removed through a short posterior incision. The second stage (ten days later) is done through a Haight anterolateral incision. Anterior segments of ribs 2-3-4 are resected and the two operative areas combined into one. At the third stage (ten days later) the short posterior wound is opened and posterior segments of ribs 5-6-7 are resected. All three stages are thus completed in twenty days. Since the majority of the disease is located in the posterior half of the chest the major focus and source of the sputum are attacked immediately at the first stage. The solid anterior chest supports the cough mechanism and sputum is markedly reduced before anterior rib segments are removed at the second stage. The amount of surgery at each stage is more evenly distributed and the speed of completion accounts for the excellent collapse pattern. The short posterior incision preserves muscle function and insures good use of the upper extremity.

The *A P P thoracoplasty* (anterior stage, posterior stage, posterior stage), as used by Dr Harold Kipp, consists of an anterior stage at which long segments of ribs 1-2-3 and their respective cartilages are removed. At the second stage, two weeks later, the short posterior segments of ribs 1-2-3 are removed, plus longer posterior segments of ribs 4 and 5. At the third stage two weeks later, posterior segments of ribs 6-7-8 are removed. In seven-rib thoracoplasties a longer period of recovery is allowed between the first and second stage in order that posterior segments of all seven ribs may be removed at the second and last stage. This operation is designed for large apical cavities which have invaded the anterior half of the chest. The sputum is quickly reduced after the first stage so that a large second stage may be performed. If the cavity is not significantly reduced by the first and second stages the Monaldi procedure as outlined above may complement the operation. Its main theoretical disadvantage is the inability of the patient to cough well after the first stage, but with proper nursing attendance and pressure dressings this hazard is overcome. The distribution of surgery at each stage is such that shock is rarely experienced.

Thoracoplasty over a pneumothorax is often preferable to attempts at re-expansion. To acquire the desired pattern of collapse, air is removed from the

pleural space as fast as the ribs are resected. It should also be remembered that theoretically rib resection without removal of air might allow for the development of a positive intrapleural pressure sufficiently high to interfere with the returning blood flow. It is advisable, therefore, to take intrapleural readings and withdraw air frequently during the thoracoplasty.

Thoracoplasty with extrafascial refills of air (Aycock operation). A modern selective thoracoplasty is done with the resection of long segments of ribs. In some cases the collection of subscapular fluid and air is not great and only a fair collapse is obtained. If this is true, refills of air may be given into the subscapular pocket, through the axilla, in accordance with the usual pneumothorax technic. In this way subclavicular depression is abolished. The weight of a 5 pound shot bag placed upon the bulging pectoral muscles is then transmitted to the air and from the air to the lung. By this technic a better collapse may be maintained between stages.

Thoracoplasty with delayed rib resection and with extrafascial refills of air (modified Bailey procedure). At the first stage the periosteum is stripped from the first two to five ribs, but the ribs are not resected.* Refills of air are given into the subscapular pocket to maintain maximum collapse. At the second stage the thoracoplasty is completed but the ribs are still not resected. Refills of air are continued until the collapse pattern is fixed by beginning rib regeneration. At the third stage the bare ribs are resected. This procedure is best used in a 16 or 17 year old girl, because scoliosis is almost absent as long as the ribs are in place and when they are finally removed the spine is already fixed by the new regenerating set of ribs.

TECHNIC IN TREATMENT OF TUBERCULOUS EMPYEMA

The empyema of tuberculosis was formerly managed by the grotesque Schede procedure. Now it is handled by (1) decortication alone; (2) thoracoplasty alone; (3) decortication and thoracoplasty in combination; (4) thoracoplasty and pleurectomy; (5) resection, pleurectomy and thoracoplasty; (6) combined procedures (lobectomy, decortication, pleurectomy and thoracoplasty). The use of streptomycin is probably essential to success.

Decortication alone is used only when the etiological focus was extremely small and has had sufficient time for firm and secure healing during the period of pneumothorax collapse. Decortication and re-expansion in these rare cases may be done without reactivation of disease.

Thoracoplasty alone is reserved for the small tuberculous empyema, often apical, in a patient with a thin parietal pleura. Air and fluid are removed as the thoracoplasty progresses with obliteration of the pleural space. Rib resection and drainage with a tight fitting well-placed catheter is often done as a first stage procedure. The operative field of the first stage procedure is not entered at the second stage when the actual

* We have also used an inflated surgeon's glove placed beneath the ribs. Plastic bags cause less fluid to form

thoracoplasty is done. Active suction insures obliteration of the pleural space and a good collapse pattern.

Decortication and thoracoplasty is designed for the patient with a good bacteriological result whose upper lobe (usually) is extensively diseased, but whose lower lobe is comparatively free of disease (laterals and serial x-rays). Re-expansion of the upper lobe would be dangerous and undesirable since no return of function could be hoped for in a destroyed lobe. Re-expansion of the lower lobe, however, not only improves the patient's function, but obliterates the tuberculous dead space as well. Through a standard posterolateral incision the fifth rib is resected and dissection in the extrapleural plane is carried upward behind the fourth rib to the thoracic vault. The pleural space is then entered by incising the thickened parietal capsule along the bed of the resected fifth rib. The parietal element extending to the vault and already free from the overlying ribs is resected and the lower lobe decorticated. Two tubes (an anterior and a posterior one) are used for intrapleural suction. Active suction is established. The thoracoplasty is completed by the resection of ribs 4-3-2 at a later stage. The periosteum without the thick parietal capsule molds itself in and around the inexpandible upper lobe and the lower lobe fills the lower half of the thorax on this side.

Thoracoplasty and pleurectomy is designed for the patient with a small apical (usually) empyema with a good bacteriological result, but whose parietal pleura (capsule) is so thick that little or no collapse can be expected from thoracoplasty alone. The parietal element is removed as in the procedure above and the thoracoplasty rib resection completed last. The periosteum falls to mold itself over the collapsed upper lobe. No drainage is necessary.

Resection, pleurectomy and thoracoplasty is reserved for the patient with a positive sputum and a destroyed lung with or without a bronchopleural fistula. A standard incision is made, the fifth rib resected and the empyema circumscribed by dissection in the extrapleural plane. Once the operator is beyond the bounds of the empyema the pleural space proper is entered and the resection performed in the usual manner. A thoracoplasty is done in one or two stages three weeks later to obliterate the pleural cavity. Breaking into the empyema cavity by accident or by necessity does not seem to alter the result.

The combined procedure, lobectomy, decortication, pleurectomy and thoracoplasty, is designed for the patient with a positive sputum coming from a visible focus in a destroyed upper lobe whose lower lobe is free of disease (tomography) but inexpandible and whose parietal pleura is too thick for a localized upper thoracoplasty to be effective. All procedures may be accomplished in one stage, but a two-stage procedure is the usual plan. At the first stage the fifth rib is resected, the lower lobe

decorticated and an upper lobectomy performed. Active tube suction insures re-expansion. At the second stage (three weeks later) the apical pocket is entered, the parietal pleura freed in the extrapleural plane, excised, and then thoracoplasty completed by resection of ribs 4-3-2. If the apical pocket is small the thoracoplasty without the pleurectomy may be sufficient.

SEGMENTAL RESECTION TECHNIC

Segmental resection is the latest refinement in resection technic. It requires a profound knowledge of pulmonary anatomy and is designed to preserve the maximum amount of lung function.

The technical point to be emphasized is the identification, isolation and division of the offending bronchus *before ligation of any vessel*—especially before ligation of a vein. After the bronchus is divided and the proximal end closed, traction and gentle dissection on the distal end soon discloses the vessels which accompany it. *Only the artery* is ligated and divided, the vein is preserved as long as possible since it receives tributaries from the adjacent segments. Only tributaries from the diseased segment should be ligated. The marginal vein is visible, therefore, on the raw area of the unresected segments.

The technic of re-expansion is almost as important as a meticulous anatomical dissection of the segment. These patients, after segmental resection, have a few alveolar "leaks" or fistulas which are not conspicuous except when the anesthetist increases the positive pressure sufficiently to maintain full re-expansion of the lobe. Since full and complete re-expansion of the residual segments is essential to the preservation of maximum function, *active* intrapleural suction is imperative—preferably with anterior and posterior tubes. A single intrapleural tube dropped beneath water as a water seal acts *only* as a safety valve. It is a passive attitude toward re-expansion and requires that the pressure in the pleural space be positive before air escapes into the bottle. Yet even by this method (water seal) the fistulas finally close and as the air and fluid are gradually absorbed the segment expands. During this lag, however, irreversible changes may have occurred to the parietal, diaphragmatic and visceral pleurae so that, instead of preserving function, the respiratory reserve is actually decreased. This is especially true should an empyema develop in the dead space before reexpansion has occurred.

It is physiological to maintain a negative intrapleural pressure. This can be done by regulating the speed of suction even though many small alveolar fistulas are present. The actual intrapleural pressure may be determined by connecting the anterior intrapleural tube to a pneumothorax machine (T-tube). If a negative pressure of a 8 to 15 cm. of water is maintained the segment *immediately* occupies its proper volume and

the raw area soon seals itself against the chest wall, the diaphragm, mediastinum or adjacent lobes, depending upon the segment removed. A bronchogram at a later date reveals the residual segment occupying an area that justifies the operation.

Bailey identifies, isolates and clamps the offending bronchus. Then to better delineate the segment, 5 to 15 cc. of hydrogen peroxide and methylene blue are injected into the bronchial lumen distal to the clamp. A second clamp closes the opening into the bronchus. After division of the bronchus the blue segment is gently teased from the adjacent pink ones.

TECHNIC IN ESOPHAGEAL RESECTION

The defect, after esophageal resection, has been bridged in four ways: (1) by a plastic cutaneous tube (Torek); (2) by an end-to-end anastomosis; (3) by duodeno-esophageal anastomosis; and (4) gastro-esophageal anastomosis. The Torek procedure is now obsolete; the end-to-end anastomosis can be used early in very small lesions; the duodeno-esophageal anastomosis requires preparatory operations for mobilization of the duodenum; but Garlock and Sweet have convincingly demonstrated the value of the gastro-esophageal anastomosis.

Gastro-esophageal Anastomosis.—In the left-sided gastro-esophageal operation with the lesion above the aortic arch (Fig. 188), the patient is placed in the standard thoracotomy position and draped with the arm, shoulder, and lower neck in the sterile field. The left 7th rib is resected and the 6th and 8th ribs are divided just in front of the transverse processes. The thoracic esophagus is mobilized and the thoracic duct ligated if necessary. If the growth is adherent to the opposite lung the mediastinal pleura is opened widely and the lung cautiously liberated. Visibility may be improved by ligation of the azygos vein. It is advisable to mobilize the arch of the aorta by ligation of the intercostal and esophageal arteries, since the stomach is to occupy the retro-aortic region later in the operation. Garlock in the first case reported of a cervical gastro-esophageal anastomosis brought the stomach anterior to the arch. We have followed Wiley's plan of bringing the esophagus behind the arch to gain length.

The diaphragm is opened in a radial fashion from the hiatus outward and the stomach is mobilized almost to the pylorus by dividing the vasa brevia, the left gastric, and the left gastro-epiploic arteries. The blood supply of the stomach consists thereafter of the right gastric and the right gastro-epiploic arteries. The preservation of the anastomosis between the left and right gastro-epiploic vessels along the greater curvature is a technical point to be stressed. The esophagus is divided at the cardia and the latter turned in in two layers.

A vertical incision 3 inches long is made parallel to the lower part of the left sternocleidomastoid muscle. Dissection is carried down along the lateral border of the thyroid to the esophagus. The inferior thyroid artery and recurrent laryngeal nerve are identified. The lower cervical esophagus is mobilized by placing the left index finger up through the thoracic wound and the right index finger down through the cervical wound. The esophagus is divided between clamps (Fig. 189) and the proximal end delivered into the cervical wound. Traction sutures are

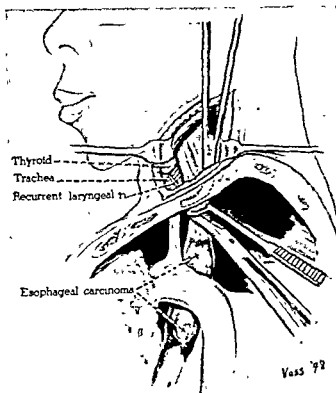


Fig 188.—The esophagus is divided at the level of the clavicle. The proximal end is delivered into the neck where traction sutures are placed proximal to the clamp. The traumatized end of the esophagus is then resected between the clamp and the traction sutures.

placed and the traumatized portion of esophagus removed with a sharp knife.

Two heavy traction sutures are placed in the fundus of the stomach, threaded upward behind the mobilized aorta, through the superior aperture of the thorax into the cervical wound. In this way the stomach is delivered into the cervical wound where a standard two-layer gastro-esophageal anastomosis is done. Fixation sutures at the superior aperture, along the vertebral gutter, and at the diaphragmatic crux prevent gastric recoil and tension on the suture line. The gastro-esophageal anastomosis is dropped into the depths of the cervical wound and the latter

closed with drainage for forty-eight hours. Left lung re-expansion is aspirated from the side immediately if there is any doubt about the dimensions of the existing hemopneumothorax.

The right-sided approach is favored by some surgeons especially for lesions at or above the level of the aorta. The abdomen is opened first and the stomach mobilized as above. The patient is turned on his left

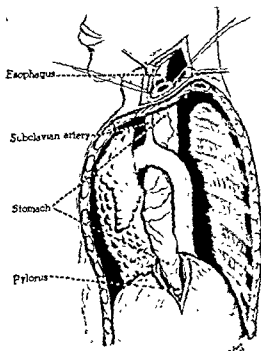


Fig 189—Heavy traction sutures are used to deliver the stomach from behind the aorta into the supraclavicular region. Traction on these sutures are maintained until sutures along the vertebral gutter have firmly fixed the stomach in its new position. The anastomosis is then accomplished without tension upon the suture line.

side and the right chest opened. The esophagus is mobilized, the right crux of the diaphragm divided if necessary, and the stomach pulled into the thorax. The anastomosis is standard, and re-expansion is maintained by an intercostal tube dropped below water. The technical disadvantage of this plan is that the resectability of the lesion is not known until after the abdominal stage is performed. Its main advantages are the accessibility of the esophagus, and the preservation of diaphragmatic action which is important in the prevention of postoperative pulmonary complications.

Preservation of diaphragmatic action in older patients with low respiratory reserve can be accomplished in the left-sided approach by

utilization of two surgical teams. The first team opens the chest and determines the resectability. The second team then opens the abdomen even though the patient is lying on his right side. By gravity the left lobe of the liver tends to fall away from the surgical field. The stomach is mobilized as above. The left crux of the diaphragm is often not divided before the stomach is delivered into the thorax. The technical advantages of this plan are that the resectability of the lesion is known first and the diaphragmatic action is preserved. The technical disadvantages are the circumstances under which the abdominal team must work, since exposure is not easily obtained.

TECHNICS IN SURGERY OF THE HEART AND ITS VESSELS

The past ten years have seen the development of a new field in thoracic surgery; namely, surgery of the heart and great vessels. This work is extremely complicated and should be undertaken only in environments where radiologist, internist, cardiorespiratory physiologist, anesthetist and surgeon can closely coordinate their respective skills in achieving a desired result.

In *wounds of the heart* the surgeon should (1) use fine interrupted suture material; (2) use free or pedicled pericardial grafts when necessary; (3) drain the pericardial cavity into the pleural cavity to prevent cardiac tamponade. He should not place sutures through the endocardium (mural thrombus).

Foreign bodies of the heart have been repeatedly removed by Harken who recommends that two rows of sutures be placed, one on either side of the proposed line of incision before opening the ventricle. Immediately after removal the sutures are tied across the incision, closing it with a minimal amount of blood loss.

Cardiac arrest is best treated by: (1) cardiac massage, (2) the Wiggers "defibrillator"; (3) intravenous procaine; and (4) artificial respiration with use of manual compression upon the anesthetic bag. Intracardiac adrenalin is of questionable value especially early during the period of ventricular fibrillation.

Ligation of a patent ductus arteriosus may be accomplished by complete division (Gross) or by simple ligation. If a ductus is short, thin walled or of large diameter it may be ligated with umbilical tape or by wrapping the vessel with cellophane subsequent to tying each end of the ductus.

The *tetralogy of Fallot* has been handled ingeniously by Blalock and Taussig. In order to increase the flow of blood through the lungs, Blalock has performed an end-to-end anastomosis of the innominate or subclavian arteries to one of the pulmonary arteries. Potts accomplished a similar result by side-to-side anastomosis of the aortic arch to the left pulmonary artery. Holman recommended an end-to-end anastomosis of

the subclavian artery and the right pulmonary artery. The latter was designed to prevent kinking of the subclavian or innominate arteries.

Transposition of the aorta, a congenital anomaly, has not been corrected yet in the human being. In experimental animals, Hanlon and Blalock have designed an operation to solve this problem by performing an anastomosis between the right pulmonary veins and the right auricle or superior vena cava. In this way, the right heart would receive oxygenated blood which is then delivered by the transposed aorta to the systemic circulation. This same procedure may prove of practical value in certain cases with the tetralogy of Fallot in which the transposition of the aorta is so great that the "usual" Blalock operation is disappointing.

Coronary arterial occlusion may be treated by the resection of the cardiac infarct. Such operations have been performed successfully in animals, and attempted in man by Gordon Murray.

Aortic and mitral stenosis have been successfully treated by Cutler, Bailey, Smithy and others. Technics consists of using various types of valvulotomes and incising the valve leaflets. A cardiac insufficiency is substituted for a stenosis.

The "bloodless heart" for open cardiac surgery is still in the experimental stage. Gibbon, Crafoord and Björk have each developed an "artificial heart" which maintains cerebral circulation for rather prolonged periods in order that the surgeon may operate upon the heart in a bloodless field. Björk and Crafoord have a machine which oxygenates and decarbonates the blood and acts as a mechanical heart. In their experimental animals the venae cavae and azygos veins were ligated, the heart opened and later closed, with complete recovery of the animals. It is conceivable that this experimental work will one day be applicable to the human being.

Aortic aneurysms have been wrapped with polythene cellophane by Poppe and Abbott. The results are encouraging. An intense proliferation of fibrous tissue is stimulated and the pain seems to disappear.

Coarctation of the aorta is being corrected by Crafoord, Gross and others. The aorta is resected between clamps and end-to-end anastomosis is performed. Gross used an everting suture while Crafoord prefers a layer-to-layer anastomosis. Claggett, Johnson and Kirby have operated on patients in which the coarcted segments were too long to permit end-to-end suture of the divided aorta after resection. In two of these cases, after a manner described by Blalock, they ligated the proximal divided end of the aorta, dissected the left subclavian artery and ligated its distal end and anastomosed its proximal end to the distal aorta. This procedure might extend the scope of operability to some cases of coarctation previously considered inoperable.

BRONCHOGRAPHIC ANATOMY OF THE LUNGS

J. GORDON SCANNELL, M.D.*

INASMUCH as bronchography is primarily a method of mapping pathological changes in the bronchial tree and not merely demonstrating that such changes exist, a clear concept of bronchial anatomy is essential to its proper execution. It would serve little purpose here to enter into the controversy over matters of terminology, to propose a new nomenclature, or modify an old one. To be clinically useful, a system of bronchial nomenclature must be as simple and concise as accuracy permits. Two such systems are currently in wide use; the one that has been so clearly presented by Mr. Brock in his monograph on the anatomy of the bronchial tree, and the other which was proposed by Jackson and Huber in 1943 and subsequently adopted by Boyden. According to the latter system, which will be used in this paper, the segments of the lung are designated by their position in the lobe rather than their relation to adjacent mediastinal or parietal structures. Except for the matter of nomenclature, there appears to be quite general agreement as to the disposition and topography of the bronchopulmonary segments. Granted that these may be correctly considered the surgical units of the lung, it must be remembered that only under certain circumstances are they suitable for individual resection.

Although familiarity with the anatomy of the lung is essential to the making as well as the interpretation of bronchograms, the actual technic of introducing the opaque oil may best be left to the individual operator. The basic requirement of a satisfactory bronchogram is adequate filling of all the segmental bronchi to the part of the lung under consideration. Under most circumstances, this will mean the delineation of all the segments, and may be carried out one side at a time. It should be emphasized that the filling of normal segments is of equal if not greater importance than the demonstration of disease, since the decision as to whether or not a segment should be preserved may depend upon positive bronchographic evidence that it is within normal limits. Under many circumstances a complete picture of the bronchial tree may not, or cannot, be readily obtained, but the degree of incompleteness should be accurately appraised. The distinction between adequacy and completeness of filling requires the clinical judgment that raises bronchography above a technical level.

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One might close this preamble by remarking that it is generally undesirable to employ bronchography in the diagnosis or evaluation of lung tumors. The problem here rarely calls for localization beyond the lobe involved or the level of bronchial encroachment. The former can almost always be determined on the basis of plain films in several projections

from a variety of causes, not the least of which are accumulations of

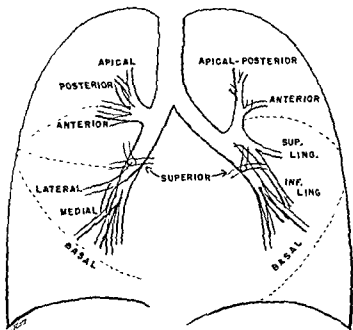


Fig 190 — Diagram of postero-anterior projection of a bronchogram. Although this view may be useful to demonstrate that disease is present, its usefulness in localization is limited to the superior segments of both lower lobes, the upper segments of the left upper, and perhaps the medial basal segment on the right. The difficulties in differentiating the basal segments and the segments of the middle lobe are apparent.

mucus or other material in the bronchial lumen, and the introduction of lipiodol may forever confuse the interpretation of parenchymal shadows.

In his monograph, Brock has presented excellent diagrams of the bronchial tree and its relation to the chest wall radiographically. These, together with his many photographic reproductions of actual bronchograms, serve admirably as a bronchographic atlas. For a more detailed analysis of the prevailing pattern and common variations, the reader is referred to the papers of Boyden and his associates, particularly if he is concerned with the problems of bronchovascular anatomy.

Since the lung is very much a three dimensional organ with the bron-

chial tree branching at its center, views in several planes are needed for accurate localization. By x-ray, postero-anterior, lateral and oblique films are necessary. Of the oblique films, the left anterior oblique, by projecting the right lung field away from the spine, is most useful for the right bronchial tree, and conversely, the right anterior oblique for the left side.

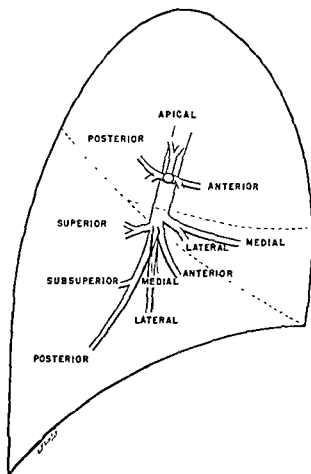


Fig 191.—Diagram of right lateral projection of bronchogram—right side only. This view is the most useful for demonstrating all the segments on the right except the medial and lateral basal. One side only—preferably the right—should be filled, since if both sides contain oil there is usually confusing superimposition (*cf.* fig. 194).

The three lobes of the right lung contain ten segments—three in the upper lobe, two in the middle lobe, and five in the lower lobe. The two lobes of the left lung are made up of eight segments in all—four in the upper and four in the lower lobe. However, in theory at least, it seems reasonable to suppose that there is an equivalent number of segments on the left, but that, by virtue of the lesser volume of the left pleural space, two segments have been combined with neighboring segments to reduce the total from ten to eight.

On the right side, just below the level of the carina, the upper lobe bronchus arises perpendicular to the main stem on its upper and outer aspect. The right upper lobe bronchus is short and characteristically divides into three segmental bronchi—apical, anterior and posterior. Two points of confusion may arise here. First, there may appear to be two apical segmental bronchi, and secondly, an “axillary” segmental branch may be demonstrated. In the former instance, Boyden has shown that the

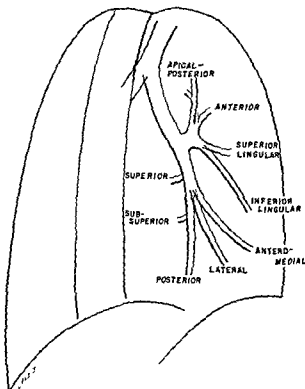


Fig 192.—Diagram of right anterior oblique projection. This view is necessary for proper demonstration of the left bronchial tree which is brought into profile away from the shadow of the spine. This is the classic position to demonstrate the lingular segments.

anterior of these apical branches may be considered an accessory apical branch arising from the anterior segment. This variation occurred in almost one-third of fifty lungs studied by careful dissection. In the second instance, namely the appearance of an “axillary” segmental branch, the weight of recent anatomic evidence favors the view that this is the posterior ramus of the posterior segmental bronchus arising coordinately with the anterior segmental bronchus, or rarely a large lateral ramus of the anterior segmental bronchus which has arisen conjointly with the anterior ramus of the same segment. In any event, since such

an "axillary" bronchus is found in less than a quarter of specimens, it is felt that it should be considered a variation of the prevailing pattern and not be accorded recognition as a segmental bronchus, a view heretofore quite generally held. The bronchial pattern of the right upper lobe can be best appreciated in the lateral projection.

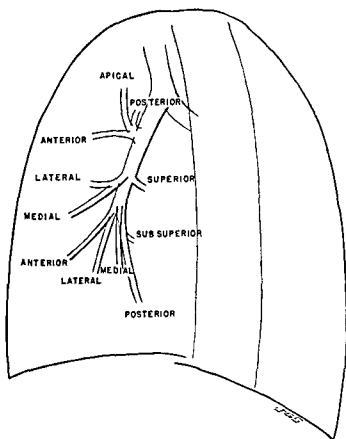


Fig 193.—Diagram of left anterior oblique film. This view will bring the right bronchial tree into relief and may supplement the right lateral projection (Fig 191).

The bronchi of the right middle lobe, on the other hand, usually require all three standard views—i.e. *postero-anterior*, *lateral*, and *oblique*—for their orientation. The middle lobe typically has two segmental bronchi arising from a comparatively long lobar bronchus which, in turn, arises from the anterolateral aspect of the stem bronchus* at about the level of the superior segmental bronchus of the lower lobe, the so-called "dorsal division." The segments of the middle lobe are generally acknowledged to be medial and lateral, and these can usually be distinguished without particular difficulty.

* "Stem bronchus" is used here and elsewhere in this paper as a generally descriptive term and not to indicate a specific portion of the bronchial tree

However, the bronchi to the lower lobe pose great difficulties to accurate identification, especially the basal segments which are considered to be four in number—medial, anterior, lateral and posterior. The remaining segment of the lower lobe, namely the superior segment, or "dorsal division" according to time-honored clinical usage, can usually be readily identified in all views. The superior segmental bronchus arises from the posterior aspect of the stem bronchus at the level of the middle



Fig 191—Reproduction of a right lateral bronchogram. Although the filling is light, the ten segments on the right are shown, with the medial and anterior basal segments arising from a common stem (*cf* fig 191)

lobe orifice and supplies the upper third of the lobe. Boyden and Smith have made extremely interesting studies of the variations of topography of this segment which is clinically so important. The superior segmental bronchus has three subdivisions—superior, lateral and posterior.

The branching of the stem bronchus in the manner of the familiar elm, plus the fact that the branches are so often distorted by the ravages of disease and are prone to fill poorly because of retained secretions, make differentiation of the four basal segments difficult. Under favoring

circumstances, however, identification of medial, anterior, lateral and posterior basal segments can be made. One other bronchus to the basal portion of the lower lobe deserves mention, namely, the subsuperior bronchus which arises from the stem bronchus below the superior segment but has been considered distinct from the posterior basal. Its size,



Fig. 195.—Reproduction of right anterior oblique bronchogram of a 7 year old boy with extensive bronchiectasis involving all the segments of the left lower lobe and the superior and inferior lingular segments of the left upper. Although ravaged by disease, the architectural plan of the left bronchial tree is preserved.

distribution and level of origin vary within wide limits, but it can usually be identified with relative certainty on the lateral film.

The arresting feature of the left bronchial tree, as opposed to the right, is the comparatively long course of the left main bronchus as it makes its way beneath the arch of the aorta, and incidentally also beneath the arch of the left pulmonary artery, before giving rise to the left upper lobe bronchus. The latter is wide and short, and in the majority of instances bifurcates into a superior and inferior (lingular) division. Of these, the former carries two segments—an apical-posterior (a combination of the

analogous two segments on the right), and an anterior segment which extends athwart the lobe. In about 25 per cent of cases a tripartite division of the upper lobe bronchus is found. Boyden and Hartmann have demonstrated that the central limb of this trifurcation is the anterior segmental bronchus, and its downward displacement in this manner is usually accompanied by the appearance of an accessory anterior bronchus arising from the apical-posterior segment.

The inferior division of the upper lobe bronchus, which is commonly referred to as the lingular division, carries two segments, the superior and inferior lingular, which are oriented one above the other in contrast to the arrangement in the analogous middle lobe on the right. Brock has convincingly demonstrated this. The pattern of the left upper lobe, particularly the lingular branches, is best demonstrated in the right anterior oblique position. The importance of complete delineation of the lingula when bronchiectasis is present in the left lower lobe was established by Churchill and Belsey ten years ago.

The branching of the left lower lobe is comparable to the right lower with two notable exceptions. The superior segmental bronchus has no middle lobe to come off in juxtaposition to it, and therefore can be more readily seen on the postero-anterior projection than its fellow on the right side. Secondly, the medial and anterior basal segments are combined to form a rather sizeable branch which frequently pursues a distinctive curving course along the left border of the cardiac silhouette. The remaining segments of the lower lobe are the lateral and posterior basal, plus a subsuperior bronchus similar to that on the right. From the point of view of radiological diagnosis, they are a little easier to identify with assurance than the basal segments on the right.

By way of summary, the following outline of the segmental anatomy of the lung is presented. For completeness Brock's terminology is given parenthetically, plus the system of enumeration suggested by Boyden.

THE BRONCHOPULMONARY SEGMENTS

Right Upper Lobe

- 1 Apical (*apical*)
- 2 Anterior (*pectoral*)
- 3 Posterior (*subapical*)

Right Middle Lobe

- 4 Lateral (*lateral*)
- 5 Medial (*medial*)

Right Lower Lobe

- 6 Superior (*apical*)
- 7 Medial basal (*cardiac*)
- 8 Anterior basal (*anterior basal*)
- 9 Lateral basal (*middle basal*)
- 10 Posterior basal (*posterior basal*)

Left Upper Lobe

- 1 + 3 Apical-posterior (*apical-subapical*)
- 2 Anterior (*pectoral*)
- 4 Superior lingular
- 5 Inferior lingular

Left Lower Lobe

- 6 Superior (*apical*)
- 7 + 8 Antero-medial basal (*anterior basal*)
- 9 Lateral basal (*middle basal*)
- 10 Posterior basal (*posterior basal*)

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THE CONSERVATIVE MANAGEMENT OF EN

ROBERT B. GREENBLATT, M.D.* AND ROLAND R.

ENDOMETRIOSIS is, in the main, a disease of young women. In the past, conservatism in the management of patients with this condition has met with but varying degrees of success. It has been only in recent years that this entity, described in 1899 by Russell¹ and brought into prominence in 1921 by Sampson,² has been accorded the therapeutic consideration it deserves. In the past, laparotomy performed for the removal of endometrial lesions, while preserving ovarian and childbearing functions, has afforded partial or complete relief of symptoms for a considerable period but has been followed in not an inconsiderable number of instances by other pelvic operations. Conception has followed conservative operations on women in whom endometriosis may have been the cause of infertility. Present interest in the use of hormonal therapy offers further hope for the control of endometriosis until the patient has acquired a family, and when employed with conservative surgery will tide a woman over a good part of the childbearing age yielding better results and preventing some reoperations. Radical surgery, i.e., panhysterectomy, should be reserved for the patient over 35 years of age.

Novak³ defined endometriosis as "the condition in which tissue resembling more or less perfectly the uterine mucous membrane occurs aberrantly in various locations in the pelvic cavity." In 1938, Meigs⁴ drew attention to the fact that endometriosis was increasing in frequency and suggested delayed marriage and the lack of early and frequent childbearing as possible factors. Thierstein and Allen⁵ reported a definite yearly increase in a proportionate number of cases over previous groups.^{6,7} Sampson⁸ stated that next to leiomyoma of the uterus, endometriosis probably furnishes the most frequent pelvic lesions found at operation in women between the ages of 30 and the menopause. During a one year period he reported thirty-seven cases of endometriosis in 170 abdominal operations for pelvic disease in women between 30 and 50 years of age. Meigs⁹ made a gross diagnosis of endometriosis in 36 per cent of 400

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Aided by a grant from Schering Corporation, Bloomfield, N. J. The supplies of testosterone pellets (Oreton-F) and progesterone pellets (Oreton-M and Oreton) were made available through the courtesy of Dr. W. H. Stoner and Dr. Edward Henderson of Schering Corporation.

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consecutive private female patients at laparotomy, with pathologic confirmation in 28 per cent. Only 5.8 per cent of 400 consecutive patients who had abdominal gynecologic operations at the Massachusetts General Hospital showed microscopic evidence of endometriosis. He concluded that patients in a general hospital population have less endometriosis than patients in private practice. Holmes¹⁰ reported eighty proved cases of external endometriosis among 307 gynecologic laparotomies, an incidence of 26 per cent. He stated that endometriosis was a disease of middle menstrual life with an incidence of 78 per cent between the ages of 30 and 45 years in the reported group of cases.

Because of the increasing importance of endometriosis, we believe it worth while to report our experiences with hormonal therapy in the conservative management of a number of cases selected from our series of patients with this disease

CASE REPORTS

Endometriosis of Abdominal Wall

CASE I.—P S., a 27 year old white woman, was first seen in July 1940 complaining of dysmenorrhea of two years' duration. She had been married eight years but was childless. She had had a miscarriage in 1934. In 1936 a bilateral salpingectomy, ovarian resection and incidental appendectomy were done. The pain of which she complained when consulting us was in the right lower quadrant, began as discomfort on the day prior to the onset of menses, became very severe during menstruation and persisted as soreness for about ten days following cessation of the flow. Her menstrual periods occurred regularly every twenty-eight days. Examination showed a right inguinal hernia. The uterus was retroverted, there was a tender mass in the right adnexa, and a small mass in the abdominal wall which became indurated and painful at about the time of menses.

Laparotomy was performed two weeks later. A large cyst containing a viscous, dark brownish fluid was present in the right ovary. The ovary and cyst were removed. The left ovary showed evidence of previous resection and was left intact. The retroversion was corrected by defundation and suspension and the hernia was repaired. A small mass was excised from the external oblique muscle.

Pathologic Report: Hemorrhagic endometrial cyst of the ovary about 4 cm in diameter. Sections of nodule excised from abdominal musculature revealed endometriosis (Fig. 196).

The patient did well after the operation until November 1946. Menstruation had continued to be regular but was scanty. She complained of nervousness and a more or less constant pain in the pelvis and back. This pain did not increase during menses. Pelvic examination revealed some tenderness and induration of the uterosacral ligaments. It was felt that there had been a mild recurrence of the endometriosis and three 75 mg. pellets of testosterone were implanted subcutaneously. The patient was rechecked two months later and it was noted

that the pain had subsided. She was still nervous but had gained 4½ pounds. There was a slight increase in hair growth on the upper lip, the clitoris had enlarged slightly and libido had increased. The tenderness on pelvic examination had disappeared.

The patient returned for further observation nine months after pellet implantation. Pain had been relieved for six months, after which time there was a recurrence of mild backache. Menses had remained regular and scanty. At this time three 75 mg. pellets of testosterone were again implanted. Satisfactory alleviation of symptoms was noted during the seven months following and the patient has remained fairly comfortable to date (February 1, 1949).



Fig. 196.—Endometrioma of abdominal wall.

Endometriosis of the Cervix

CASE II.—J. S., a 22 year old white woman, was first seen in September 1946 for the study of sterility. She had been married five years and had never been pregnant. She also complained of pain in the lower abdomen and back which began about one week before the onset of menstruation, became most severe during menses and then persisted as soreness for several days. Further inquiry revealed poor sex urge, dyspareunia and pain on defecation during the menstrual period. Her husband was found to have aspermia.

On pelvic examination there was extreme tenderness in the cul-de-sac but no nodules were palpable. Gross inspection of the cervix showed a minute, hemorrhagic, cystlike lesion on the anterior lip, about 0.3 cm. in diameter. A presumptive diagnosis of pelvic endometriosis was made and the lesion on the cervix

was suspected of being an endometrial implant. The patient stated that a dilatation and curettage had been done fourteen months previously without benefit.

She was given 25 mg of testosterone propionate parenterally every few days for a total of ten injections. At the end of this course of therapy the patient noted marked alleviation of her symptoms. The lesion on the cervix was biopsied, and microscopic examination revealed an endometrial implant on the surface of the section of the portio (Fig 197).

Because of the gratifying results obtained with parenteral androgens, three pellets of 75 mg. each of testosterone were implanted subcutaneously on November 25, 1946. Relief from pain continued and after five months there was only slight evidence of the old symptoms. Slight hoarseness had developed, the clitoris had increased to about one and one-half times the original size, there



Fig. 197 —Endometrial implant on portio

(Wilson)

ng by Jack

was no acne and very little increased hair growth. Menses remained regular and bleeding took place from a *progestinal endometrium*.

Six months after implantation there was a recurrence of symptoms and oral methyl testosterone, 10 mg. twice daily, was instituted. Satisfactory alleviation of pain resulted. However, the hoarseness became marked and sore throat developed. It was felt that further androgen therapy was contraindicated and it was discontinued.

In September 1947 the patient returned because pain had been very severe during the last menstrual period. Four 50 mg. pellets of progesterone were implanted. The patient noted about 50 per cent alleviation of pain during the following eight months but she admitted that relief was not so great as that following oral testosterone therapy. Her libido had decreased under progesterone therapy.

Estrogen therapy, in massive doses, was then instituted. The dosage was sufficient to arrest ovulation. Bleeding became irregular but was more or less painless. Three months after the start of estrogen therapy, suction curettage revealed a cystic glandular hyperplasia of the endometrium. By increasing the estrogen dosage bleeding could be arrested entirely. The patient has now been under estrogen therapy for seven months. She complains of a bearing-down feeling in the rectum but is free from pelvic discomfort. Libido has diminished greatly.

It is interesting to learn from this patient that the most gratifying relief was obtained with androgen therapy. Libido and well-being were greatest and menses were regular. Had it not been for the development of persistent sore throat she would have preferred to continue this form of therapy. Estrogens have proved satisfactory in lessening pelvic pain but the menstrual cycle has been completely disturbed, with only spotting occurring now and then, and libido is at its lowest ebb.

Ruptured Endometrial Cyst

CASE III—A A, a white woman 35 years of age, was first seen in July 1947. She had one child born in 1943. At the time of her visit she complained of severe crampy pain in the lower abdomen and backache during each menstrual period. She noted tension and soreness of the breasts just before the onset of menses. Her libido was poor and intercourse was painful. Pelvic examination revealed induration in the cul-de-sac and nodular thickening of the uterosacral ligaments. The induration in the cul-de-sac was so marked as to give the impression of retroflexion of the uterus. However, on probing the uterus it was found to be anteфлекed. Insertion of the curette into the uterus for suction biopsy on the eighth day of her cycle did not cause uterine spasm. Pathologic report showed the endometrium to be in the follicular phase. A presumptive diagnosis of pelvic endometriosis was made.

It was decided to treat the patient conservatively and she was placed on methyl testosterone. The patient reported marked improvement in symptoms during the following seven months. She had almost complete relief from dysmenorrhea, soreness of the breasts had gone, and premenstrual tension was greatly reduced. She stated that during one month when she omitted taking the methyl testosterone the symptoms recurred, but they were promptly alleviated following resumption of therapy.

On March 1, 1948 the patient developed symptoms and signs of an acute abdomen. Emergency laparotomy was performed and a ruptured chocolate cyst of the ovary was found and removed. The diagnosis of endometrial cyst was confirmed by microscopic examination (Fig. 198). The patient made an uneventful recovery. Postoperative examination revealed that the extensive induration previously palpated in the cul-de-sac had disappeared. A few months later mild pelvic pains began to recur with the menstrual period and three 75 mg. pellets of testosterone were implanted. Satisfactory alleviation of symptoms

has been experienced by the patient to date (nine months later). Arrhenomimetic phenomena have been minimal, appearing only as slight growth of hair on the upper lip

Successful Pregnancy Complicated by Ureteral Endometriosis

CASE IV—E S, a 24 year old white woman, was first seen in September 1943. She complained of extreme pain in the lower abdomen during the menstrual period and for one week following cessation of flow. The pain was so severe that her physician gave her some opiate each month for relief. She had one child, born in 1941, and longed for another child. Pelvic examination revealed

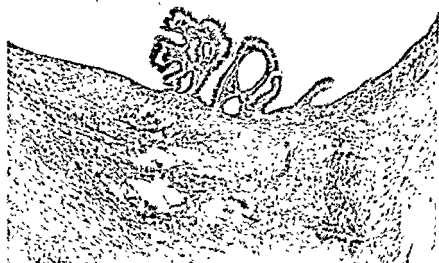


Fig 198—Endometrial cyst of ovary

a retroverted, adherent uterus, tenderness and some bulging in the left fornix and tender enlargement of the left ovary. A tentative diagnosis of endometriosis was made. She was given 100 to 125 mg. of testosterone propionate each month in 25 mg. doses by injection every fifth day for a period of six months with complete relief of symptoms. The pain recurred about two months after cessation of therapy, therefore testosterone therapy was re-instituted and she received several similar courses lasting six months each followed by rest intervals of two to three months between courses. Her syndrome was ameliorated under this treatment.

The patient returned in April 1946 complaining of excruciating pain in the left side radiating down the thigh accompanied by marked dysuria. The attack had been present for a week following menstruation. A catheterized specimen of urine revealed many red blood cells. The patient was referred for urologic examination. The urologist concurred in the diagnosis of endometriosis and felt that the pain was produced by an endometrioma causing pressure on the ureter.

Three 75 mg. pellets of testosterone were implanted this time and the patient was relieved of pain during the next six months.

This patient was seen again in November 1946 because of recurrence of her pain. Pelvic examination showed the uterus still retroverted but slightly more moveable. There was tenderness in the left fornix and some induration of the left uterosacral ligament. Three 75 mg. pellets of testosterone were again implanted. There was no pain following the next menstrual period. Shortly thereafter the patient became pregnant but aborted early in February. She became pregnant again very soon thereafter and carried to term successfully. She was delivered of a normal male infant on November 29, 1947.

Metrorrhagia Complicating Endometriosis

CASE V.—I. J., a 25 year old single white woman, was hospitalized in May 1947 because of metrorrhagia of four weeks' duration. She experienced severe, cramping abdominal pain during the last week prior to admission. The only significant finding on pelvic examination was a retroverted uterus of normal size. In June 1947 dilatation and curettage, uterine suspension and incidental appendectomy were performed. With the abdomen open the operator noted an endometrial cyst of the left ovary and two endometrial implants in the cul-de-sac. The ovary was resected and the implants removed. The patient improved and was asymptomatic until December 1947. At this time she began to have severe dysmenorrhea and menorrhagia. The pelvic pain radiated down both legs. Another dilatation and curettage was performed in January 1948. While under anesthesia pelvic examination revealed the uterus to be of normal consistency but enlarged to twice the normal size. Impression at this time was adenomyosis with endometriosis.

On February 3, 1948 a single injection of 75 mg. of testosterone propionate was administered intramuscularly for metrorrhagia and dysmenorrhea. The relief was dramatic. On February 25, 1948 three 75 mg. pellets of testosterone were implanted subcutaneously. Approximately four weeks after the implantation the patient had a normal menstrual period lasting four days with practically no dysmenorrhea. This was the first such menstrual period she had had in two years. Follow-up during the next nine months revealed complete alleviation of her symptoms. She had noticed no side effects from the testosterone therapy.

Massive Hemorrhage in Cervical and Rectal Endometriosis

CASE VI.—A. J., a white woman 35 years of age, was first seen in March 1948. She complained of dyspareunia and constant pain low in the pelvis as if something were pressing against the rectum. Pain during menses was particularly severe and bleeding was somewhat excessive. At this time pelvic examination revealed an indurated mass in the cul-de-sac which on pressure referred pain to the rectum not unlike the pain the patient felt all along. She volunteered the information that the feeling of fullness in the pelvis increased just before each menses. Two years previously the patient had suffered a massive hemorrhage per rectum and sigmoidoscopic, proctoscopic and x-ray studies following barium enema had failed to reveal the cause.

This patient was treated for several months with androgens with a degree of relief which had not been obtained from any other therapy. However, she protested the further use of androgens after learning from her physician-husband that androgens are masculinizing.

Laparotomy was done and evidence of endometrial transplants along the bladder fold attachment to the anterior wall of the uterus was found. Small transplants were present on the posterior wall of the uterus. The anterior wall



Fig 199—Endometrioma of posterior cervix at the point where anterior rectal wall was attached

of the rectum was indurated and adherent to the lower segment of the uterus. Separation was difficult but sufficient to allow a total hysterectomy. Histopathologic study revealed an endometrioma (Fig. 199) occupying the posterior portion of the cervix where it was attached to the rectal wall. The ovaries appeared normal and were not disturbed. Operation, however, failed to relieve the pain of rectal pressure. This is not surprising since some of the endometrial tissue was incorporated in the rectal wall and was not removed. A course of androgens now seemed expedient and the patient agreed to the administration of 25 mg. of testosterone propionate at weekly intervals. After the seventh injection she reported disappearance of the rectal discomfort. In retrospect it was felt that the intestinal hemorrhage was due to the endometrioma described above.

COMMENT

The treatment of endometriosis is difficult. The choice lies among hormonal therapy and watchful waiting, surgical intervention, and irradiation. Consideration must be given to the severity of the symptoms,

the extent and location of the lesions, the age of the patient, and her sentiments towards the removal of her menstrual and childbearing functions. Radical excision or irradiation castration, often necessary for cure, will precipitate a severe menopausal syndrome.

Conservatism may be hormonal treatment alone, conservative surgery, or both. In young women with mild complaints, surgery may be postponed with the hope that the pelvic condition will subside, or that pregnancy will occur. Cashman¹¹ stated that the policy of deferring laparotomy until the patient is older, if disability does not force the issue, results in fewer reoperations and better end results.

Beecham¹² wrote that conservative surgery in the treatment of endometriosis is the predilection of all gynecologists. He felt that conservative surgery meant the removal of the least possible tissue to obtain the desired result, and that every attempt should be made to preserve ovarian function to the age of 45 years or beyond. Dannreuther¹³ mentioned that 40 per cent of chocolate cysts and widespread endometriosis occurs in women less than 35 years of age. Normal ovarian tissue should be conserved in these young women, but in women over 35 years, the conservation of ovarian tissue was of little importance. Hurd¹⁴ felt that it is probably wiser to be a little more radical in patients with endometriosis than in the average gynecological cases, because very few will become pregnant again, and because symptoms are liable to persist as long as ovarian tissue remains. Meigs¹⁵ concluded that the treatment of endometriosis should consist of conservative surgery, with the destruction or removal of small areas of ectopic endometrium, in women desiring children. Radical surgery was suggested in the older age group, that is, removal of all involved tissue with the preservation of ovarian function. Radiation, he felt, should be used if growth continued. He added that the results of radical treatment were excellent, but that from 9 to 26 per cent of reoperations were necessary following conservative surgery.

Sanders¹⁶ expressed the opinion that the treatment of endometriosis was entirely surgical. He stated that the principal question was the relief of symptoms, and the prevention of further damage by interruption of the disease. He felt that the use of radium or x-ray was hardly justifiable, since the exact diagnosis could not be proved without exploration, and the associated pathologic conditions invariably present was not relieved. Morse¹⁷ was of the opinion that the ovaries should be preserved if possible in young women, but in the woman who has had numerous children and whose reproductive activity was drawing to a close, the excision of the ovaries was of less significance. Cashman¹¹ postponed surgery as long as possible, and then removed the uterus and major lesions in the ovaries, attempting to preserve all the ovarian

tissue possible. Counseller and Sluder¹⁸ felt that the ovaries of patients of any age group should not be removed unless it was necessary, but especially not those of patients less than 40 years of age. They added that either the endometriosis or the ovaries must be completely removed in order to expect a surgical cure and that a high percentage of the secondary and tertiary pelvic laparotomies was required because of previous incomplete operations.

Patients with endometriosis frequently are sterile. The uneventful delivery of a woman afflicted with severe endometriosis is still uncommon.^{19,20,21} In the presence of endometriosis and pregnancy, abortion, premature labor and extrauterine pregnancy often occur. Complications in labor, such as rupture of the uterus, atony during cesarean section and critical postpartum hemorrhage, are frequent.⁷ On the other hand, Graves,²² Cattell and Swinton²³ and Meigs¹⁵ are of the opinion that inasmuch as most conservative operations are done for preservation of childbearing, it is essential to note that from 9 to 32 per cent of patients become pregnant subsequent to operation. However, Counseller²⁴ doubted whether conservative surgical procedures materially improved the chances for pregnancy and seriously questioned whether they should be undertaken with that possibility in mind. Scott²⁵ found only forty-seven reports of endometriosis in pregnancy in the literature and added two of his own. McIlrath²⁶ reported two cases, one with tubal endometriosis associated with an intrauterine pregnancy. Lock and Myers²⁷ added two cases in which conception followed conservative measures for endometriosis. Both patients, one of whom was treated with testosterone for dysmenorrhea, had a normal prenatal course, delivery and puerperium. These authors searched the literature and concluded that approximately one-third of patients treated conservatively can successfully conceive, and that the majority of such patients have a normal pregnancy.

In 1943 Hirst²⁸ presented a summary of the information from the literature which established a rational basis for the use of androgens in the therapy of endometriosis. He stated that this type of treatment was practical for advanced cases where radical excision was contraindicated or refused.

Many authors have attested to the merits of androgen therapy.^{29,30,31,32} The positive values, according to Hirst,³³ appeared to be the rapid reduction of pain, tenderness and swelling of grossly cystic ovarian endometriomas. This form of therapy is of value as a diagnostic test if the symptoms are subdued following its use. He added that androgens will not cure endometriosis and have but a temporary action. He recommended androgen therapy in the form of intramuscular injections of 150 to 225 mg. of testosterone propionate in oil for two to three weeks, followed by daily oral dosage of 10 mg. of methyl testosterone continued up to three

or four years. Although more expensive than pellet implantation, he mentions that this method is more controllable. We have used pellet implantation in many patients with excellent results. Following a short therapeutic test with parenteral or oral androgen therapy to determine if the patient's complaints are alleviated by this medication, as many as three 75 mg. pellets of testosterone may be implanted subcutaneously. The advantages and method of pellet implantation have been described in a previous article.³⁴ This method of therapy has produced satisfactory alleviation of symptoms preoperatively and has controlled residual or recurrent endometrial lesions following conservative surgery. There has been no difficulty in the control of dosage. Arrhenomimetic phenomena have been mild. Most patients feel that the inconvenience of slight hirsutism, acne and enlargement of the clitoris is compensated by the marked improvement. The patients return of their own accord for additional implantation of pellets when there is any symptomatic suggestion of recurrence of the syndrome.

Experience has long pointed to the disadvantages of estrogen therapy. Reactivation of endometrial tissue has resulted from this form of therapy.³⁵ In recent years, however, several investigators have used massive doses of estrogens to inhibit ovulation persistently for many months to a year and longer. Karnaky,³⁶ among others, has been most enthusiastic about this form of therapy. More has to be done along this line to establish its worth and if substantiated it will change many fundamental concepts concerning the etiologic factors in endometriosis.

SUMMARY

The incidence of pelvic endometriosis is increasing. The condition occurs more frequently among patients in private practice than those in a general hospital population. Endometriosis probably is one of the most common pelvic lesions found at operation in women during active menstrual life. The role of androgens in therapy has been defined by an extensive literature on the subject. The value of massive doses of progesterone has as yet not been established. Estrogen in small dosage aggravates endometriosis but, experimentally, estrogens in massive doses over a prolonged period of time have in a certain number of patients yielded surprisingly good results.

The treatment of endometriosis has not been satisfactory. Most authors agree that every attempt should be made to conserve ovarian and childbearing function. Approximately one-third of patients treated by conservative surgery may conceive and the great majority of such patients have a normal pregnancy. The policy of deferring laparotomy until the patient is older results in fewer reoperations and better end results. The use of hormonal therapy offers further hope for the control

of endometriosis Androgen therapy in the form of testosterone pellet implantation has been followed by successful alleviation of symptoms for periods of six to eight months. Satisfactory amelioration of the syndrome may also be obtained with parenteral and oral androgen therapy. These are particularly useful as a therapeutic test before pellet implantation. The advantage of the pellet mode of therapy is the tremendous convenience afforded the patient by a single treatment.

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THE DIAGNOSIS OF ECTOPIC PREGNANCY

L. V. DILL, M.D., F.A.C.S.*

ECTOPIC pregnancy has been known since the days of Abulkasis (1100 A.D.), and in 1604 Riolan described the classical clinical picture. The first operative procedure for this diagnosis was carried out in 1883 by Lawson Tait, and since the general use of asepsis and anesthesia, operative removal of the affected area has been utilized exclusively in the treatment of this condition.

The incidence of ectopic pregnancy varies with the part of the country and the type of clientele, but in general is noted to be from 1 in 100 to 1 in 300 live births. It is more frequent in the colored than in the white race, and in the age group around 25 to 30 years.

Since ectopic pregnancy is one of the most frequently missed gynecologic diagnoses which carries a serious prognosis, and since facilities are now available to reduce the mortality of this complication of pregnancy to a minimum, the diagnosis should be considered as a cause of abdominal pain in any woman in the childbearing age. The obstetrician or gynecologist is rarely the first to see a person with an ectopic pregnancy, therefore it is necessary for the general practitioner, the general surgeon, and even the nongynecologic specialist to be cognizant of the characteristics of the condition.

SYMPTOMS

The most important and most constant symptom of ectopic pregnancy is *pain*, and so rarely is it absent that it may be considered to occur in all cases. The pain associated with rupture is described as being of sudden onset and midline, with migration later to one side (around 50 per cent), but it may be unilateral (around 30 per cent), upper abdominal (5 to 10 per cent), or even in the back (rare). This pain may be dull and aching, or cramping, but is usually intermittently dull and sharp.

The next most frequent symptom is that of a *missed menstrual period*, and although this is difficult to ascertain with accuracy in some cases, due to irregular bleeding and lack of record in the menses, only 10 to 20 per cent of the patients give no clear-cut history of missed menses.

Bleeding of irregular nature is a frequent symptom. From 30 to 50 per

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cent of the patients will be bleeding on admission, whereas 70 to 90 per cent will give a history of irregular bleeding. This may be simple spotting, may resemble menstruation, or may occasionally be noted as real uterine hemorrhage with the passage of clots and tissue.

The urge to defecate with the onset of pain is noticeable more frequently than allowed by coincidence, and is seen in from 20 to 30 per cent of all patients in whom a viscus is already ruptured.

Shoulder pain, referred to the suprascapular region on one or both sides, occurs in 10 to 20 per cent of the cases in which rupture has taken place.

Nausea and vomiting, breast symptoms of tightness and engorgement, and urinary frequency and dysuria, are noted in the same incidence as in the normal intrauterine pregnancy until after the onset of pain, at which time nausea and vomiting occur in an additional 5 to 15 per cent of the patients.

Syncope is a variable symptom depending on the time at which patients seek medical aid: (1) those who call a doctor at the first sign of pain or bleeding rarely experience this phenomenon, and (2) those patients who go to a doctor late, develop syncope in 50 to 80 per cent. Fainting may be an accompaniment of a normal early pregnancy or in association with severe pain, but in general, in the ectopic pregnancy, it is associated with sudden massive blood loss.

SIGNS

The most frequent sign to be noted in the ectopic pregnancy is abdominal tenderness, which occurs in from 85 to 95 per cent of the patients. This tenderness is localized to the lower abdomen, is usually more noticeable on the side of the implantation, but may be generalized. Rebound tenderness is present early in most of the patients in whom rupture has already occurred. The incidence of this sign is dependent on the presence of blood in the abdomen, and is consequently dependent on the stage at which the complication is seen.

It must be stressed that frequently, after a rupture has been allowed to bleed for several hours and the abdominal cavity is distended with blood, pain, tenderness and rigidity may disappear almost completely, leaving a soft, "doughy," nontender and nonrigid abdominal wall.

Equally as frequent is a sign that is well recognized but rarely stressed in the diagnosis of the ectopic pregnancy—*exquisite tenderness and pain produced by manipulation of the cervix*. This occurs in around 90 to 95 per cent of the patients, is entirely out of proportion to the temperature and elevation of the white blood count, and is of great significance when taken together with the remainder of the signs and symptoms.

The third most frequent sign, and one of the most important if determined to be present, is an *adnexal mass*. The incidence is 60 to 70 per cent in palpable form in the conscious patient, but is actually 100 per cent in patients at laparotomy. Therefore, the acuity of the examiner and the ability of the patient to cooperate play a large part in determining the incidence of this sign. The pain produced by pelvic examination is usually so great as to cause lack of cooperation on the part of the patient, making it difficult or uncertain to determine the size and shape of the uterus, the presence or absence of cul-de-sac or adnexal masses, and the definition of other pelvic structures. Under general anesthesia the incidence of finding a pelvic mass changes, and approaches 95 per cent.

Bulging of the cul-de-sac, shifting dullness, and flank dullness, all depend on the presence of large amounts of blood in the abdominal cavity. These signs are recognized in from 20 to 40 per cent of patients, again depending on the stage of the condition when the patient is first seen.

Another important sign, particularly in those cases in which bleeding has not been rapid but has been prolonged over several days, is the presence of *anemia* definitely out of proportion to the blood loss noted externally. This occurs, along with pallor and elevation of the pulse rate, in 50 per cent of the patients.

The presence of *shock and syncope* on admission depend on the type of clientele and the stage of the tubal pregnancy. In some groups shock is present in no more than 5 per cent of the patients; in others it may reach 15 per cent. It may be stated that shock, when present, is by far the most important sign.

LABORATORY DATA

The laboratory findings are mentioned for the sake of completeness, but are usually of little value in the diagnosis of the acute ectopic syndrome. The hemoglobin, red cell count and hematocrit are frequently moderately depressed, but not necessarily so.

Time is rarely available to obtain a test for urinary gonadotropin, and the routine urine specimen is usually essentially negative.

In the questionable cases in which observation is being carried out, a steadily dropping hemoglobin, red cell count and hematocrit, along with a positive test for urinary gonadotropin, are of great value.

DIFFERENTIAL DIAGNOSIS

The types of errors in diagnosis which arise in differentiating the ectopic pregnancy from other pelvic conditions vary with the type of clientele and the stage of the condition when the patient is first seen. The private patient operated on erroneously for an ectopic pregnancy

usually has an intrauterine pregnancy or an angular pregnancy (20 to 40 per cent). A similarly incorrect diagnosis may be made on patients threatening to abort, but fewer of these have laparotomies. Salpingo-oophoritis, ovarian cysts, fibromyomas of the uterus, and appendicitis are less frequently confusing.

In clinic patients the specific pelvic inflammatory conditions produce the greatest incidence of error in the diagnosis of ectopic pregnancy, and threatened or induced abortion is close behind. Intrauterine pregnancy, angular pregnancy, ovarian cysts, myomas and appendicitis follow.

We have found that the following plan of attack helps a great deal in mapping the course of therapy for a patient who has a questionable ectopic pregnancy. First it must be decided: (1) Does this patient have an acute abdomen? And (2) is it almost undoubtedly not salpingo-oophoritis? If the patient has an acute abdomen, or is shocked, or we do not feel that it is salpingo-oophoritis, there is no choice but laparotomy to rule out an intra-abdominal catastrophe.

In those patients in whom there is a questionable abdomen, and salpingo-oophoritis is thought to be ruled out, we feel that posterior colpotomy, a cul-de-sac puncture, or culdoscopy is definitely indicated. The procedure to be followed would then depend upon the results of this diagnostic measure.

Where there is no question of an acute abdomen and the signs and symptoms would lead one to think of ectopic pregnancy, we feel that these patients should be hospitalized, blood made available, and the patient kept under careful observation. In general, the picture will become definitely clarified within a week.

The simple expedient of checking the positive findings by the following list has been of great value in making the diagnosis of an ectopic pregnancy, and will render the diagnosis clear in seemingly obscure cases:

- | | |
|-------------------------|---|
| 1. Pain | 7. Anemia |
| 2. Abdominal tenderness | 8. Shoulder pain |
| 3. Cervical tenderness | 9. Urge to defecate at onset of severe pain |
| 4. Missed period | 10. Shifting dullness and bulging of cul-de-sac |
| 5. Mass in adnexa | |
| 6. Bleeding | |

Shock has not been included because its significance is out of proportion to the other signs and symptoms.

SUMMARY

The signs and symptoms of ectopic pregnancy have been presented, and frequent complications have been seriously considered in the presence of any abdominal pain in the woman of childbearing age.

INVERSION OF THE UTERUS

GEORGE SCHAEFER, M.D.* AND EDWARD C. VEPROVSKY, M.D., F.A.C.S.†

IN the course of his practice the obstetrician may never see more than one or two cases of inversion of the uterus. Yet, so dramatic is this accident of labor and so important are its recognition and treatment that a review of the entire subject with a report of three cases is not amiss.

Incidence.—Since Valentine de Vitry first reduced an inverted uterus of sixteen months' duration in 1847, numerous papers have been written on this topic. Thomas¹ reviewed fifty-eight cases from 1769 to 1869 of which eighteen ended in death. In 1911 Thorn, quoted by Irving,² found 641 cases reported. The older literature gives the incidence of inversion of the uterus as one in several hundred thousand;³ however, more recent authors give an incidence of about 1 in 5000 cases.^{2, 4, 5, 6, 7} Polak⁸ and Hirst⁹ have each reported six personal cases. Our incidence at the Queens General Hospital is 3 cases in 19,301 deliveries or 1 in 6433.

Classification.—Inversion of the uterus may be *incomplete*, in which the uterine fundus does not extend farther than the cervix, or *complete* (Fig. 200) in which any part of the corpus passes through the cervical ring. Phaneuf¹⁰ classifies inversion into three varieties: (1) *acute*, which occurs immediately after delivery before the cervical ring has formed, (2) *subacute*, which is found after the cervical ring has formed, and (3) *chronic*, which has existed for one month or more postpartum and in which involution has taken place.

ETIOLOGY

Several points of view have been advanced for the occurrence of inversion of the uterus. Most textbooks give the impression that this accident is due to mismanagement of the third stage of labor and is caused by undue pressure on the fundus or traction on the cord. Others^{7, 11, 12, 13} believe that inversion may occur spontaneously due to contraction of the muscle fibers of the fundus with relaxation of the lower uterine segment. Slavin¹⁴ studied inversion in cows, 90 per cent

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of which deliver themselves. He found the incidence in cows to be 1 in 517 births and noted that it was infrequent in primipara except after abortion. He also found that the removal of an adherent placenta did not cause inversion, nor was inertia a cause. The causes of inversion of the uterus may be listed as *predisposing* and *exciting*.

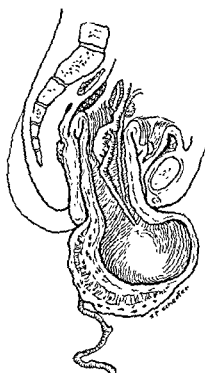


Fig. 200 — Complete inversion of the uterus with the placenta and cord attached.

Predisposing Causes

- 1 Pathologic Conditions of the Uterus and Its Contents
 - a Adherent placenta
 - b. Short cord
 - c. Congenital weakness or anomalies
 - d Weakening of the uterine wall at the placental attachment
 - e. Congenital failure of improper innervation
 - f Chronic metritis
 - g. Effect of difficult labor, frequent pregnancies or abortions
 - h. Fundal implantation of the placenta
 - i Tumors
2. Functional Conditions of the Uterus
 - a. Inertia
 - b. Relaxation of all parts of the uterus
 - c. Disturbance of the contraction mechanism

Exciting Causes

1. Manual removal of an adherent placenta
2. Increase in intra-abdominal pressure
3. Mismanagement of the third stage of labor
 - a. Improper fundal pressure
 - b. Traction on the cord
 - c. Injudicious use of oxytoxics

Harer and Sharkey¹⁵ collected twenty-one cases of which 16, or 76 per cent, were classified as avoidable and 5, or 24 per cent, as spontaneous or unavoidable. They felt that increased intra-abdominal pressure due to coughing or vomiting, plus the abnormal distribution of fibers in the fundus at the site of the placental attachment and the softening of the uterine wall at this area due to increased vascularity, may lead to the production of a dimple on the fundus of the uterus. The actual mechanism of inversion is described by Phaneuf as follows: "After any portion of the uterus becomes indented to a considerable extent, the rest of the organ seizes this invaginated portion as it would a foreign body, and in attempting to expel it, turns itself inside out." Gordon¹⁶ offers pathologic proof of this from a postmortem examination. The placenta was attached to the fundus and sections from various parts of the uterus other than the placental site were normal. A section of the placental site showed definite destructive action in the myometrium. The weight of the placenta could cause a depression in such a weakened myometrium and the over-active uterine muscle of the remainder of the wall would seize and expel it as it would a foreign body.

Charbonnet¹⁷ reported a case in which the placenta was catapulted with such a force by an inverting uterus that it struck the attendant who was standing two feet away. He ascribes this to the intravenous use of an oxytoxic. Another example of the role of oxytoxics in the production of inversion is cited by Kaltreider⁷ who on injecting ergotrate intravenously during a cesarean section saw the uterus invert through the incision.

SYMPTOMS

The symptoms of *hemorrhage*, *shock* and *pain* are well known. Examination will reveal whether the inversion is complete or incomplete. Spain¹⁸ states that the shock associated with inversion is due to the stretching of the nerves of the broad ligament and the peritoneum which have been dragged into the inverted uterus. Browne¹⁹ attributes the shock to compression of the ovaries in the cervical constriction similar to that produced by injury to the testicle. Since the shock produced by inversion

may at times be out of proportion to the blood loss, these explanations should be considered.

CASE REPORTS

CASE I—R S (No A5426), a 25 year old white primipara, was admitted at term to the Queens General Hospital on December 25, 1939 in active labor. After a first stage of thirty-eight and one-half hours and a second stage of four and three-quarter hours, she was delivered of a 6 pound stillborn infant by low forceps. The third stage lasted fifty minutes and the placenta was delivered by moderate fundal pressure without traction on the cord. What appeared to be a succenturiate lobe remained in the vagina and the membranes attached to it were grasped with a clamp but could not be delivered. The mass in the vagina was not replaceable and since the patient began to show signs of shock—her blood pressure was 40/20 and her pulse 140 per minute—she was given a blood transfusion of 1000 cc. No further attempts at replacement were made at this time.

On December 28, 1939 the mass in the vagina was still present and under ether anesthesia it was repositied vaginally and the uterine cavity packed with gauze. The patient was given a sulfonamide, ergotrate and repeated blood transfusions and on December 30, 1939 the packing was removed. On examination of the patient for discharge from the hospital on January 15, 1940 the vagina was filled with the body of the inverted uterus; the cervix could be palpated at the upper end of the mass and the actual area of inversion felt. The patient had no complaints and signed herself out of the hospital against advice.

She was readmitted on February 19, 1940, having begun to bleed three days after leaving the hospital. Examination at this time revealed the cervix to be dilated 6 cm., with a firm, smooth, globular mass presenting through the external os. On February 27, 1940 a Spinelli operation was performed following which the patient made an uneventful recovery and was discharged on March 15, 1940.

CASE II—E. C (No A55144), a 21 year old white primipara, was admitted at term to the Queens General Hospital on September 22, 1942 in active labor. After a twenty-two hour first stage and a one-half hour second stage she delivered an 8 pound 6 ounce infant with the aid of low forceps. The placenta delivered spontaneously one-half hour later. There was active bleeding during the third stage and the blood loss was estimated at 800 cc. On attempting to push the uterus up into the abdominal cavity, a hard mass, 8 cm. in diameter, was palpated in the vagina. Abdominal examination revealed the absence of the fundus above the symphysis.

An immediate attempt was made to reposit the inverted uterus under ether anesthesia but this was unsuccessful. The patient's blood pressure at this time was 50/0 and her pulse 160 per minute. She was given oxygen and plasma was started. When the blood pressure rose to 85/50 another attempt was made to replace the uterus. The uterus and vagina were packed with gauze and the bleeding was controlled. However, the patient coughed and the packing was

extruded, the uterus again inverting. The vagina and the uterus were repacked with gauze and the patient was given blood transfusions and a course of ergotrate. On September 25, 1942 the packing was removed and a fibroid palpated in the posterior wall of the uterus. The cervix was closed at this time and no inversion existed. About two years later in July 1944 the patient had a normal spontaneous delivery without the recurrence of the inversion and without excess bleeding.

CASE III.—A. R. (No. 61882), a 29 year old gravida III, para II, was admitted to the Queens General Hospital in active labor on September 22, 1948. Her past history was negative except for a postpartum infection following retained fragments of the placenta in her second pregnancy. Her labor was uneventful, the first and second stages lasting six hours. She did not receive analgesia or anesthesia during her labor and delivered spontaneously a 6 pound female infant in good condition. After delivery of the child, the placenta was visible at the introitus and a gush of blood appeared. A gentle Crede' maneuver was attempted without success. After a few minutes another gush of blood appeared and gentle pressure on the fundus resulted in the partial extrusion of a friable placenta. Traction on the placenta together with pressure on the fundus finally completed delivery of the placenta. A mass to which the membranes were attached appeared in the vagina. The membranes were grasped with a clamp in an attempt to twist them off and the mass in the vagina appeared at the vulva. This mass was thought to be a portion of a retained placenta and it was grasped with a sponge stick in an attempt to deliver it. When more of the mass became visible, it was recognized as inverted uterus and released, whereupon it retracted slightly into the vagina, carrying the adherent membranes with it. By this time the patient began to show signs and symptoms of shock. Her blood pressure was 60/40 and dropped rapidly to 60/0. Intravenous saline was started quickly followed by the administration of blood plasma into the veins of both arms. A blood transfusion was started and within fifteen minutes the blood pressure had risen to 90/60 and the patient was no longer in shock.

Under deep cyclopropane anesthesia an attempt at replacement of the uterus was made. No cervix could be palpated and the entire uterus was soft and flabby. Partial reposition was obtained but in attempting to pack the uterine cavity the packing was extruded on two occasions. The uterus could be elevated to the level of the umbilicus but *cupping of the fundus* was evident. It was felt that the inversion still existed. The patient had lost about 400 cc. of blood during the delivery plus an estimated 500 cc. during the attempts at vaginal replacement of the inverted uterus. She was receiving blood under pressure in both arms and her condition was good, her blood pressure being 102/70. An entire roll of 4 inch gauze was inserted against the inverted fundus and a second roll of gauze inserted against the first. The vagina was then packed with teased gauze. The entire mass consisting of packing and inverted uterus was pushed above the level of the symphysis and held up by suprapubic pressure. Since the patient was in good condition, it was deemed advisable to attempt reposition by the abdominal route.

During the transit from the delivery room to the operating room the uterus was held above the symphysis. On arrival at the operating room the patient was in shock, her blood pressure was unobtainable and her pulse imperceptible. The abdomen was opened through a low midline incision and the uterus was found high in the abdomen in good position with the inversion repositioned. There was no evidence of rupture of the uterus and the uterine cavity contained the packing that had been inserted vaginally. The abdomen was closed and the patient returned to her room. The entire abdominal procedure took less than fifteen minutes and the patient responded well, her blood pressure rising to 104/70 and her pulse dropping to 100 per minute immediately after the procedure. She received a total of 1500 cc. of blood, 1750 cc of plasma and 400 cc of saline. She also received penicillin and responded well postoperatively, showing no elevation of temperature and no bleeding at any time.

The packing was removed five days after its insertion, bringing a portion of membranes 4 by 8 inches with it. Pelvic examination revealed the fundus to be about 4 inches above the symphysis and no cupping or dimpling was palpable. The cervix was 2 inches dilated and the myometrium was visible through it. Ergonovine was given and the vagina repacked. The following day the packing was removed and the cervix was now about 1 inch dilated with small lacerations but no bleeding. Her subsequent course was uneventful and she was discharged on September 30, 1948 in good condition.

TREATMENT

Various methods have been described for the treatment of the inverted uterus. This, in itself, is an indication that no one method has widespread approval and that no one method is applicable in all cases. Barrows,²⁰ Critt²¹ and McLennon and McKelvey²² believe that the inverted uterus should be disregarded in the acute stage other than controlling hemorrhage and infection, they advise treating the inversion four to twelve weeks later. However, most textbooks and Cosgrove,⁶ Barret,²³ Henderson,²⁴ Irving and Kellog,²⁵ and Jacobs²⁶ advise immediate replacement before shock ensues. Unless this is done D'Erizzo²⁷ states "the inexperienced accoucher may waste valuable time and the golden opportunity to attempt manual replacement at once is lost." Although most men agree on immediate replacement, their methods differ. Barret advises removing the placenta, giving a quick antiseptic splash to the uterus and grasping the fundus in the palm of one hand (Fig. 201, a). He then locates the area of the cervix and vagina most easily turned in and fixes this with the other hand (Fig. 201, b). The adjacent parts are turned in until the hand is in the cavity of the uterus after which he waits until the uterus contracts against his hand. O'Sullivan²⁸ describes a method of intravaginal hydraulic pressure which he came upon accidentally. Under open drop ether he inserted a douche nozzle into the posterior fornix of the vagina. His forearm happened to block the vaginal orifice and the

vagina ballooned out, the uterus promptly returning to its correct position.

Jacobs²⁶ suggests suturing the external os after reducing the acute inversion. He used several chromic catgut sutures, reducing the lumen of the os to one-third its size and thus preventing a recurrence. Irving recommends that the Huntington operation be done without attempting vaginal replacement because the operation does not increase shock or hemorrhage which vaginal manipulation tends to do. In the Huntington operation (Fig. 202) the abdomen is opened through a midline incision and the uterus grasped with Allis forceps about $\frac{3}{4}$ inch below the inversion cup on both sides. The inversion cup is drawn up and another pair of Allis forceps grasps the uterus at a lower level and further elevates it. The first pair of Allis forceps is removed and reapplied below the second until the fundus has been drawn up and the reinversion completed.

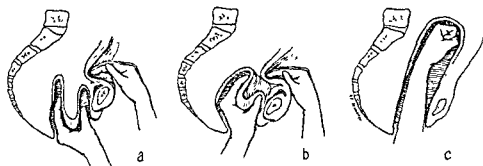


Fig 201.—a, The fundus is grasped in the palm of the hand and steady pressure made against it. b, Inversion being slowly replaced. Hand above symphysis palpates for inversion cup. c, Inversion completely replaced. Closed fist elevates fundus.

Irving and Kellog report seven consecutive cases of acute inversion treated by this method without mortality.

Clahr and Wurzbach²⁹ report a case of reduction of an inverted uterus following intravaginal packing. The vagina was packed with 25 feet of gauze placed against the inverted uterus, which was thought to be a fibroid. At laparotomy the uterus was found packed and no fibroid was present. In our Case III, in which vaginal reposition of the uterus was unsuccessful, we placed an entire roll of unwound 4 inch gauze against the inverted uterus in the vagina and supported the first gauze roll with a second 4 inch gauze roll (Fig. 203, a). We then packed the vagina and pushed the entire mass above the symphysis and held it up in place by suprapubic pressure with the fingers. Suction was apparently created by this maneuver, for the packing was found in the uterine cavity with the uterus replaced at laparotomy (Fig. 203, b).

The treatment of subacute inversion of the uterus, which one encounters from fifteen minutes to six hours after the accident, requires

astute judgement, for the majority of deaths occur in this period. Some say keep hands off and treat the shock and hemorrhage. That this view-

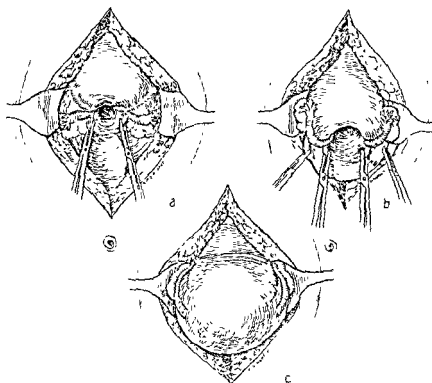


Fig 202 —Technic of Huntington operation *a*, Uterus grasped with Allis clamps about $\frac{1}{2}$ inch below the inversion cup *b*, Second pair of Allis clamps grasp below first and uterus is drawn up *c*, Reinversion completed

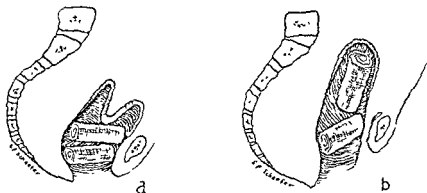


Fig 203 —*a*, Gauze pack inserted against inverted fundus A second pack placed in the vagina *b*, Position of packs at laparotomy Uterus replaced

point is sound is borne out by the mortality figures which are 5 per cent when the conservative treatment is used and 30 per cent when interfer-

ence is attempted. However, Eastman reports a death with the hands-off policy and regrets not interfering.

Numerous technics have been advanced for the reposition of the chronic inverted uterus. In 1795 John White described a method of using a round stick of wood 14 inches long and expanded at each end to avoid trauma. This was pushed against the inverted fundus. At the New York Obstetrical Society in 1865 Thomas A. Emmet spoke of a method of drawing the uterus out of the vagina and rapidly thrusting it up again. Aveling³⁰ made a cup-shaped wooden repositor to replace the inverted uterus.

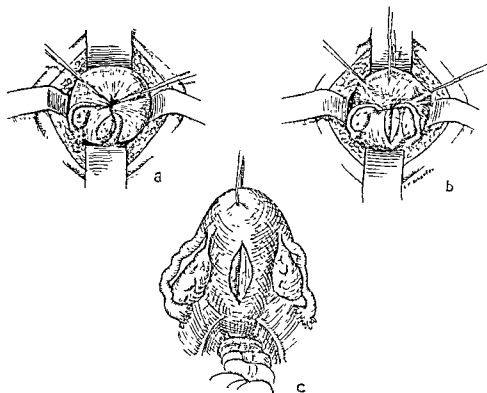


Fig. 204.—Haultain technic. *a*, Position of uterus at laparotomy. Adnexa and round ligaments drawn into inversion cup. *b*, Incision in posterior cervical constriction ring. *c*, Uterus reinverted by traction on fundus with a tenaculum.

Haultain³¹ suggests awaiting involution of the uterus. Through a low midline incision the cervical constriction ring is incised in the midline and the inversion overcome by pressure from within the vagina by an assistant (Fig. 204). The Spinelli technic (Fig. 205) consists of incising the anterior wall of the inverted uterus from the cervix to the fundus through a vaginal approach. The uterus is replaced by rolling the cut edges laterally, at the same time gently pressing the fundus up toward the pelvis. A wedge-shaped piece is excised from each side of the inverted uterus before the walls are sutured. The corpus is displaced

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THE CORRECTION OF CICATRICIAL DEFORMITIES

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SCARS usually follow the destruction of tissue resulting from trauma, burns, operation, or disease. Their appearance, their painfulness or contraction may cause a mental or physical handicap. Before operative correction is undertaken, the tissue which formed the scar must have reached a state of quiescence, recognizable by the pale color and softness of the scar. Massage and radiation often aid in accelerating the process.

In discussing the plastic repair of scars it is important to distinguish between simple and extensive scars. Both types can be smooth, hypertrophic, depressed or contracted.

SIMPLE SCARS

For correction of a simple scar, whether smooth or hypertrophic, the incision outlines the scar and penetrates at either side of the scar into the subcutaneous tissue, but not deeper. The subcutaneous tissue is kept intact to act as a basis upon which the undermined wound edges may be approximated (Fig. 206, *a*). The sutures of the wound edges are interrupted. It is customary to employ fine cotton for the subcutaneous tissue, and horsehair or fine silk on a fine curved cutting edge needle for the skin edges. The wound edges are not grasped with a forceps but only elevated by one prong to facilitate the penetration of the needle. The sutures are removed between the third and fifth day after the operation.

If the simple scar is depressed, the technic for correction differs, and should be carried out according to Figure 206, *b*. If the simple scar is contracted, the entire scar tissue, including the base, must be excised until the whole defect thus created consists of normal tissue. One ordinarily succeeds now in releasing the contracture unless the latter has been of long standing. Usually some sort of tissue shifting is necessary to close the defect. Where the contracture is due to a binding web, the Z type of relaxation incision with exchanging flaps is the operation of choice (Fig. 206, *c*). The object of this operation is to interrupt and displace the binding web by the formation and transposition of two tri-

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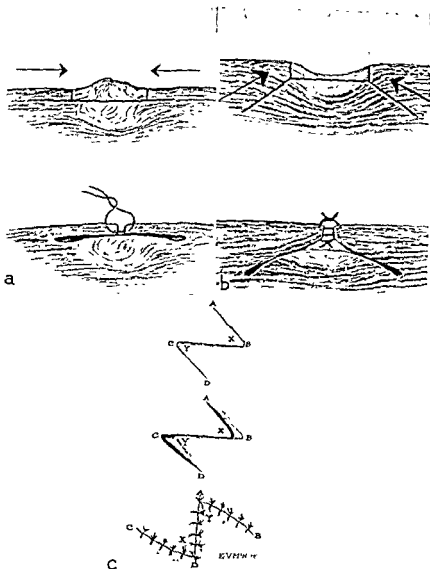


Fig 206 —*a*, Correction of simple smooth or hypertrophic scar The incision outlines the scar and penetrates the other side of the scar into the subcutaneous tissue but not deeper. The bottom of the scar is kept intact to act as a basis upon which the mobilized wound edges are approximated

b, Correction of simple depressed scar The scar is excised to the base of the retracted area. From the deep corner of the defect a bilateral incision is carried obliquely downward and outward leaving the base of the scar intact to act as a buttress. Mobilized wound edges are approximated upon this buttress

c, Z-operation for contracted scar due to binding webs The central line of the Z is laid upon the most prominent portion of the web and the arms of the Z are marked out on opposite sides of the central line in 45 degree angles. Points *A* and *B* should lie in vertical direction, so in center are *C* and *D* Thus two triangular flaps are outlined which are mobilized and exchanged The object is to interrupt and displace the binding web (note the different direction of central line). (After John Staige Davis.)

angular flaps which are placed so that their outlines form a Z. The central line of the Z is laid along the most prominent portion of the web and the arms of the Z are marked out on opposite sides of the central line. The two triangular flaps thus outlined are mobilized. The contracture is now reduced as far as possible and the two flaps are transposed. If the binding web is long, several such Z's may be formed and their flaps transposed (Fig. 207).

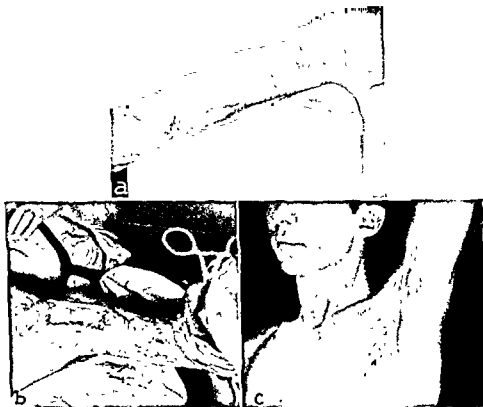


Fig 207.—*a*, Posterior view of patient with binding web of anterior part of axilla after burn
b, Condition corrected by double Z-operation, which broke up the binding and released the contracture
c, Patient three months after repair.

EXTENSIVE SCARS

Extensive smooth scars are in the same plane as the skin. Ordinarily they do not cause any trouble since they do not contract. However, they tend to become annoying if they are situated in such exposed regions as the face or neck. In these cases repair work may be requested. If the scar is not too extensive and elliptical, and the surrounding skin is freely movable, the scar is treated as if it were simple and smooth. It is excised down to the subcutaneous tissue, but not further. The wound edges are

mobilized subcutaneously and approximated until a linear suture can be established. If the defect left after excision of the scar is triangular or rectangular, and the surrounding skin is freely movable, plastic closure can be achieved by starting with closure of the corners. If undue tension in the sutures is to be anticipated, a multiple-stage procedure is advisable, by which the scar is only partially excised and sutured (Morestin, Sistrunk, Smith). During the intervals—the intervals being three months—the skin is allowed to stretch until all parts of the scar are removed. If the scar is too large to permit closure of the defect by simple tissue mobilization or tissue sliding, covering the defect by a full thickness skin graft or split graft is advisable.

The *extensive hypertrophic scar* is usually due to keloid formation. We do not know, as yet, the cause of the keloid, hence the treatment is rather vague. The most efficient treatment at the present time is radiation by x-ray or radium, preferably after excision of the scar and closure of the defect by skin sliding or skin grafting (Fig. 208).

In extensive depressed scars the technic of correction differs from that used in simple depressed scars. In the majority of cases the involved area is too large to allow an approximation of the neighboring subcutaneous tissue to fill the defect. Hence, the repair work is mostly confined to grafting fat, cutis, bone or cartilage, in order to restore the normal surface contours (Fig. 209)

Correction of *extensive contracted scars* is one of the most difficult problems in plastic surgery. The extensive contracted scar is usually caused by destruction of the deeper part of the surface tissue, and appears usually at the flexor surface of the extremities or at the junction of limb and trunk.

In the majority of cases much can be done to avoid contractures by early skin grafting. There are, however, some cases in which a skin graft operation is contraindicated because of the patient's impaired general condition. Where large grafts are not available or fail to take, immobilization of the affected limb may counteract the contracting forces during the waiting period. If in spite of proper immobilization a contracture starts developing, nothing forcibly should be done to overcome it unless the patient is ready for operation. A raw surface in the flexor region of the joints often decreases in size, not so much by the overgrowth of epithelium from the periphery of the wound, as by the drawing in of the adjacent tissue. If the process is permitted to take place without interference, healing goes on rapidly. If, on the contrary, the contracting joint is irritated by repeated forceful dressings, there will be greater production of fibrous tissue followed by more extensive shrinkage. Or, if the extremity is forcefully stretched under anesthesia and fixed in this position, wide fissures are opened in the granulating wound with the possi-

bility of infection, delay of healing, and production of larger and denser scar tissue. What really is needed in such a case is the early covering of the raw surface with a skin graft. After healing has taken place, proper



Fig 208 —a, Extensive keloid scar after second-degree burn. The scar was excised. The resulting square defect was closed by wide mobilization of adjacent skin and subcutaneous tissue, starting with closure of the corners. X-ray treatment was started two weeks after operation: 230 R, 130 KU, 40 cm distance, 4 mm. aluminum filter, ten minutes. This treatment was repeated three more times once a week.

b, No recurrence of keloid after one year. Note loss of pigment.

physiotherapy should be instituted to lessen the contracture. Further operative procedures, however, may become necessary to overcome the remaining deformity.

To correct a contracture several procedures or a combination of various



Fig 209—*a, b*, Large depressed scar and partial loss of orbital rim, with displacement of right eyebrow, after compound fracture followed by osteomyelitis. The scar was excised. To rotate the lateral half of the eyebrow downward, skin and subcutaneous tissue of forehead and scalp were widely mobilized from a long sagittal incision. A fascia lata-fat graft was transplanted into the depressed area, and the wound edges were sutured together in layers.

c, Eight months after operation.

d, Six years after operation.

procedures are available. If the contracture is caused by a *iceb formation*, and the surrounding skin is pliable, one or several Z-operations is the method of choice (Fig. 206, *a*). In contractures due to broad, dense scars, the latter are incised or excised, the contracture is reduced, and the

resulting defect is covered with a skin graft (Fig. 210). Local or distal flaps are seldom required.



Fig 210 —a, Extensive contracture of left axilla from burn.

b, The scar was incised near the chest, the contracture reduced, and the defect covered with two skin grafts. Result six months after operation.

Contractures of the hand offer additional problems. The vast majority of contractures could be avoided if the hand, whenever immobilized, were immobilized in the position of function. When the wrist is held in flexion (wrist drop), and allowed to remain in this position, the extensor tendons are maximally stretched, hence, cannot be relaxed further if an

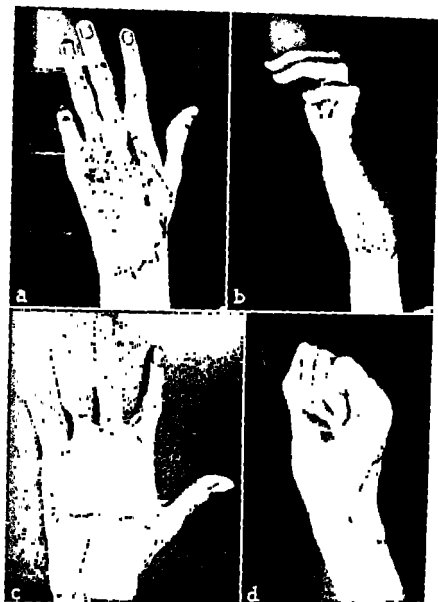


Fig 211 —*a*, Contracting keloid scar of dorsum of hand after second-degree burn
b, Marked limitation of flexion Hyperextension fixed deformity of metacarpophalangeal joints and clawhand deformity
c, d, Excision of all scar tissue at the level of the subcutaneous veins, reduction of contracture under gradual stretching, severance of collateral ligaments of metacarpophalangeal joint of fifth finger, and application of thick split grafts, six weeks after operation and extensive physical and occupational therapy.

attempt is made to close the hand to make a fist. This prevents the flexor tendons from functioning fully. It draws the fingers in hyper-

extension in the metacarpophalangeal joints, and draws the thumb back onto the side of the hand. In this position the collateral ligaments of these joints are relaxed and shortened. Prolonged immobilization in hyperextension of the fingers in this position causes a rapid shrinkage of the collateral ligaments, which prevents a normal rotation of the pha-

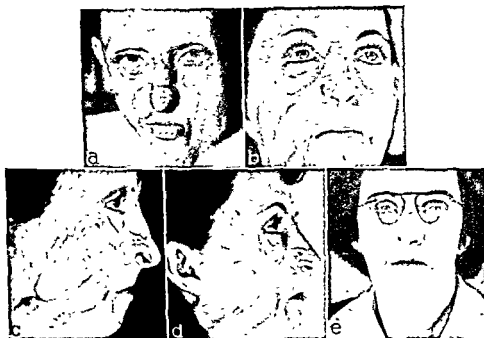


Fig. 212—*a*, Extensive cicatricial deformities of face and neck from flash powder explosion. An ectropion of right lower lip, severe contracture of chin, severe facial scars, scars around the nose, microstoma resulted from this accident.

b, Two operations were necessary to correct the extensive contracture of the neck; and one more operation to enlarge the oral orifice. The ectropion of the right lower lid was repaired with a full thickness graft taken from the supraclavicular region. The ectropion of the lower lip was corrected with full thickness graft from abdomen (see also *d* and *e*). Patient also had partial loss of right ala of nose, which was repaired with a composite graft of full thickness of skin and cartilage from the anterior part of the helix of left ear.

c, After the reconstruction of the right lower lid, and before reconstruction of the right nasal ala.

d, Patient after the finished reconstruction without make-up.

e, With make-up.

langeal joint surface over the head of the metacarpal bone. It also causes a contracture of the posterior part of the joint capsule; it increases the pull of the flexor tendons causing a flexion of the interphalangeal joint. In this position normal action of the lumbricale system is upset. The lumbricales flex the first phalanx in the metacarpophalangeal joint, and extend the last two phalanges. When the antagonists of these muscles are

contracted the lumbricales are in the position of relaxation and soon contract in this position, adding to the hyperextension of the first phalanx and partial flexion of the last two phalanges. This is the well-known picture of a "clawhand." Such a contracture can readily be prevented by immobilizing the hand in the position of function (Kanavel, Koch, Mason, Bunnell, and Bodenham), i e, extension (cock-up position) of the wrist, midflexion of the metacarpophalangeal and interphalangeal joints, and abduction and opposition of the thumb. If contractures have developed, the latter should be overcome by conservative methods in the form of elastic splinting with incorporation of elastic traction, in association with occupational and physical therapy, or by reconstructive surgery. The latter is quite often necessary in cicatricial contractures from burns; it is tedious and requires utmost skill. It consists of excision of all scar tissue, stretching of the contracted structures, immobilization of the hand, and transplantation of skin grafts (Fig. 211)

Cicatricial contractures of the neck obliterate the chin-neck line, causing an awkward straight profile. In extensive cases involving the deeper tissues, chin and lip are pulled on the chest, causing an ectropion of the lip and marked limitation of motion (Fig. 212). The correction depends entirely upon the depth and extent of the cicatricial changes. In mild cases, i e, the scar being soft and weblike, the deformity can be corrected by one or several Z-plasties. The triangular flaps for formation of the Z

in the chin-neck line, and the vertical part over the ^{1 part} ~~neck~~, and two ^{the skin} triangular skin flaps are formed, they are reflected laterally. This opens ^{new con-} ~~the skin~~ ^{he entire} ~~one able~~ ^{a thick}

split graft

SUMMARY

The repair of simple and the correction of extensive scars are discussed. Both types can be smooth, hypertrophic, depressed, or contracted. Suitable methods of repair are described for each type of scar. Especially discussed are the various methods to correct contractures of the joints and contractures of the neck. The Z-operation is the method of choice to break up webbing scars. Contractures due to broad, dense scars are repaired by incising or excising the scar, reducing the contracture, and covering the resulting defect with a skin graft, or less often with a flap.

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LAHEY CLINIC NUMBER

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THE SURGICAL CLINICS of NORTH AMERICA

LAHEY CLINIC NUMBER

SYMPOSIUM ON SURGICAL TECHNIC

RADICAL DISSECTION OF THE NECK

FRANK H. LAHEY

Because we have always had to deal with so many tumors of the neck and so many carcinomas of the thyroid, we are constantly faced with the necessity of radical neck dissection.

In a recent paper by W. A. Meissner and myself, published in *Endocrinology* and read before the American Association for the Study of Goiter, we presented our indications for radical neck dissection in malignancies of the thyroid. When frank cancer of the thyroid has occurred, has invaded and eroded the capsule of the adenoma it so frequently arises in, and has involved the parenchyma of the thyroid gland, we believe that radical and extensive neck dissection should be done, consisting of removal of all of the internal jugular from the mastoid to the clavicle and the removal of the sternomastoid from its insertion above to its attachment to the sternum and clavicle below.

Since many of these patients will have not only carcinomas of the thyroid which involve the parenchyma of the thyroid but also will have invaded the lymph nodes, many of these dissections will necessitate not only demonstration of the anatomical structures such as nerves, vessels and muscles, but will involve the removal of extensive glandular metastases from as low beneath the clavicle as possible, as far back toward the posterior triangle as possible and high up under the angle of the jaw since metastatic carcinoma, particularly of the papilliferous variety which we used to call aberrant thyroids, will involve regions thus extensively. It is for this reason that our experience with radical dissections of the neck, unlike many of the experiences of surgeons dealing with dissections of the neck for the removal of secondary gland involvement in carcinoma of the lip, tongue and mouth, will involve the frequent removal of large masses of involved tissue.

While we must also do secondary dissections of the neck for lip, tongue and buccal carcinomas, the majority of our radical dissections of the neck have been for carcinoma of the thyroid. For this reason, because of the peculiar capacity of carcinoma of the thyroid to invade particularly venous channels, we must not only include in our radical removal wide excisions of the original tumor and all of the nodes, but we must attempt to remove all of the internal jugular from the mastoid to the clavicle, together with all of its tributaries into which malignant growth could have extended.



Fig 213 —Note how the chest is thrown forward by the bar shown under the shoulders to accomplish forward projection of the area to be operated on. However, unless the bar is placed well down under the shoulders, this will decrease the distance between the chin and the sternal notch rather than increase it. Note the exaggerated rotation of the chin to the opposite side from the region to be operated on to increase the prominence of the sternomastoid and to project into the wound the structures to be removed.

One of the most important features of radical dissections of the neck is anesthesia, and intimately related to anesthesia is position. In Figure 213 is shown the amount of projection of the neck we have been able to obtain in thyroid operations and in operations for esophageal diverticula, by elevation of the shoulder bar placed well beneath the scapulae. Nothing has been more important in facilitating these radical neck dissections than the method of projecting the anatomical structures of the neck well up into the wound.

The relation of anesthesia to position is concerned with being able to have complete control of the patient at all times. With an endotracheal tube in place, as is employed by our anesthetists in all of these patients, one has at all times complete control of the patient so that there is no

obstruction to breathing and no accumulation of mucus because, if mucus occurs within the tube, the latter can be disconnected from the anesthesia apparatus and the mucus removed by suction. If no intratracheal tube is employed and there is any interference with breathing as a result of coughing and movement, the patient may so move himself out of position as to interfere seriously with the exposure and anatomical demonstration of important structures.

The next most important factor in my experience in dealing with these radical neck dissections is the type of incision employed, because unless adequate flaps are established as a primary step in the operation it will not be possible to obtain what is so important in this type of operation, namely, wide exposures above, below and in both directions laterally. One needs to be able to carry the posterior incision well back beyond the course of the spinal accessory and in front the skin incision must often be elevated and carried well over onto the other side in order to expose the opposite lobe of the thyroid to determine the presence or absence of nodules within it. In the insert in Figure 214 is shown the type of incision commonly employed by so many surgeons in radical neck dissections and the one which has served us well in this type of radical neck dissection which we have to do so often. With the oblique incision running from the sternomastoid along its entire anterior border down to the clavicle and then turned sharply backward, it is possible to obtain completely satisfactory exposures and at the same time restore the skin flaps without undue disfigurement.

With the skin flaps widely exposed, as shown in Figure 214, I have personally preferred to start the dissection by demonstration of the spinal accessory nerve posteriorly.

The most important single thing that has aided us in neck dissections has been the nerve stimulator, as shown in Figure 215. By means of this apparatus, which was supplied to us several years ago by the neurosurgeons in the clinic, who stimulated our interest in its employment, it is possible to determine the course and presence of nerves well before they are actually seen. When dissections must be done in the presence of malignancy, this is of the greatest value. When one reaches the region of the oblique course of the spinal accessory nerve, it is of greatest comfort to be able, with a mild stimulating current, to bring about the trapezius contraction that identifies the course and the direction of the nerve well before it is seen so that precautions can be employed as it is dissected out of its course. With the spinal accessory nerve completely demonstrated from where it emerges under the posterior belly of the sternomastoid, as shown in Fig. 216, down to the point where it disappears under the edge of the trapezius to become the subtrapezius plexus, the dissection can then be carried forward just above the clavicle until

the edge of the scalenus anticus can be demonstrated, and distal to it the brachial plexus, and internal to it the phrenic nerve running on its anterior surface. The phrenic nerve likewise can be demonstrated before

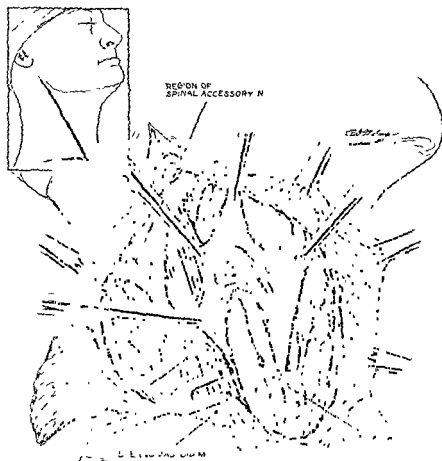


Fig. 214.—*Insert*, The type of incision which we have employed in these radical neck dissections. This heals well, as shown in Figures 218 and 219, which are photographs of two patients on whom the operation had been done several months previously.

In the above figure is shown the wide exposure made possible by dissection beneath the skin flap and wide lateral retraction. Note at "X" the region of the spinal accessory nerve which can be found, long before the nerve is seen, by stimulating this region with the nerve stimulator, thus bringing about contraction of the trapezius and betraying the exact location of the nerve so that it can be detected more easily. Note the complete separation of the internal jugular and common carotid in front of the sternomastoid to make easy the ligation of the internal jugular at its lowest point.

it appears, if there is any doubt, by stimulating the tissue on the anterior surface of the scalenus anticus with the galvanic current stimulator and watching for contractions of the diaphragm which can readily be seen through the sheet covering the abdomen. One should be careful



Fig. 215.—The stimulating apparatus employed by many neurosurgeons, by means of which the nerves can be identified by muscles they contract and their course and location determined before they are actually exposed.

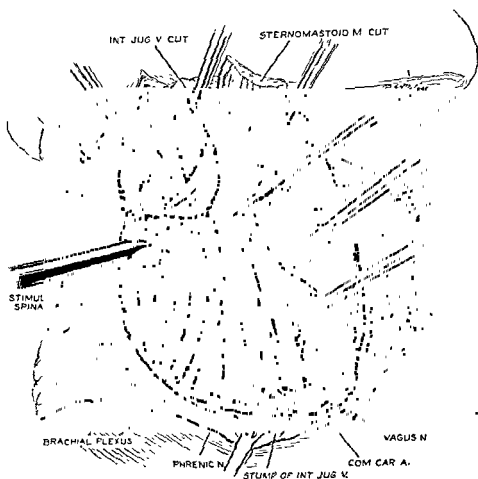


Fig. 216.—The sternomastoid has been severed, the internal jugular ligated and block dissection of the vessels, nodes and fat has been carried upward for the exposure of the underlying structures. The stimulator is placed upon the spinal accessory nerve. Note the exposed brachial plexus, the phrenic nerve, the vagus and the recurrent laryngeal nerve. Note how the thyroid gland involved in malignancy is dissected free from the trachea, carried upward and the recurrent laryngeal nerve is dissected free to the point where it enters the larynx.

in employing this stimulating current on the phrenic nerve to cut it down to a minimum intensity since stimulation of the phrenic nerve with a high current can produce quite violent diaphragmatic contractions.

With the phrenic nerve demonstrated, the brachial plexus can readily be demonstrated likewise with the stimulating current, but there is little likelihood of injuring the brachial plexus in most of the radical dissections of the neck since it is at a deeper level than the phrenic or the spinal accessory nerve. With the phrenic nerve well demonstrated on the anterior surface of the scalenus anticus, the internal jugular can be seen from behind. The prethyroid, sternohyoid and sternothyroid muscles can then be separated in the middle line until the isthmus of the thyroid is well visualized. The fibers of the sternomastoid are then best severed close to their attachment to the sternum and to the clavicle by repeated short strokes of a knife rather than by attempting to clamp and tie the vessels. By this method each small bleeding vessel in the muscle can be picked up and tied with silk and the severing of the muscles continued until the trunk of the internal jugular vein itself appears. The internal jugular vein having been identified and separated from the common carotid, with care to preserve the vagus, it is then ligated with a double silk ligature and ligated again with a single silk ligature and the dissection is then started from below upward and from without inward. This establishes a definite line of cleavage by means of which all of the anatomical structures of the neck and the thyroid can be identified step by step and made plainly visible.

With the entire mass of the sternomastoid, internal jugular and the beginning of the lateral neck dissection pulled inward and upward, the phrenic nerve dissection can be carried up along the scalenus anticus, the fat and involved glands overlying the brachial plexus can be separated upward, the course of the spinal accessory can be followed up to the point where the branch is given off to innervate the sternomastoid and this can be severed to mobilize the spinal accessory from the sternomastoid as it is turned inward toward the middle line. As the internal jugular is pulled inward and the dissection is continued from below upward, the common carotid becomes more and more visible, and as the common carotid is pulled outward by blunt dissection, the inferior thyroid artery as it passes beneath the common carotid is seen and can be ligated either external or internal to the common carotid in its position behind it.

With the inferior thyroid artery exposed, even though the thyroid gland may be involved in carcinoma, the recurrent laryngeal nerve can be identified in almost every case and dissected throughout its course. In order to do a total thyroidectomy, as is so often necessary when car-

cinoma of the thyroid has involved the thyroid gland itself and has invaded the adjacent lymph nodes, it will be necessary to ligate and sever the inferior thyroid artery so that the nerve, if it runs beneath the artery, can be exposed throughout its entire course up to the point where it enters the larynx, and thus completely preserved even though all of the thyroid gland on that side be removed.

As the thyroid is separated in the middle line from the isthmus, the isthmus on the other side is clamped and the bleeders in it are tied, the entire thyroid gland is removed, the superior thyroid artery is tied and all of the thyroid gland, sternomastoid, internal jugular and areolar tissue and nodes of the remainder of the cervical triangle are carried upward with the dissection. As the dissection finally reaches the division of the common carotid, again the stimulator will be of value in demonstrating the presence of the hypoglossal nerve, often even before it can be seen, although in most of the cases it will readily appear as it crosses the division of the common carotid into the internal and external carotids at this level.

With the hypoglossal nerve exposed, the entire thyroid removed, all of the inferior thyroid artery tied, and the spinal accessory, brachial plexus, phrenic nerve, recurrent laryngeal nerve and hypoglossal nerve in view, the dissection of the upper triangles of the neck is no longer difficult. The line of cleavage is continued upward, any involvement in the submaxillary triangle is thoroughly cleaned out, the facial vein and artery are controlled, and the dissection is carried backward until the mass of tissue in one block, as shown in Figure 217, represents attachment above only by the sternomastoid and the internal jugular vein. The dissection behind the sternomastoid well up to the point where the spinal accessory nerve disappears is completed and the dissection in front from the attachment to the ramus of the jaw is likewise completed. Again, as when the internal jugular was previously ligated, the sternomastoid muscle is gradually severed by short gentle strokes, taking pains to grasp each bleeder as it appears in the muscle until the internal jugular vein is completely identified and isolated. This structure, as was done at its lower end, is ligated with double silk and again with single silk, the entire mass is freed and the operation is then completed. All bleeding points are carefully sought for and controlled, and a rubber dam drain is placed in the central portion of the wound and made to emerge from the posterior angle of the lower portion of the incision as it runs along the clavicle. The remainder of the wound is closed with clips, and a firm bandage is applied to bring about sufficient pressure to control ooze, but not enough to interfere with breathing since one must remember that the trachea in this operation has been completely bared and undue pressure upon it from bandages can result in tracheal obstruction.

It is well to employ a silk stitch at the angle of the wound to make certain of anchoring the skin at this level, but clips may be applied in all of the remaining portion of the wound and, as in thyroid operations,

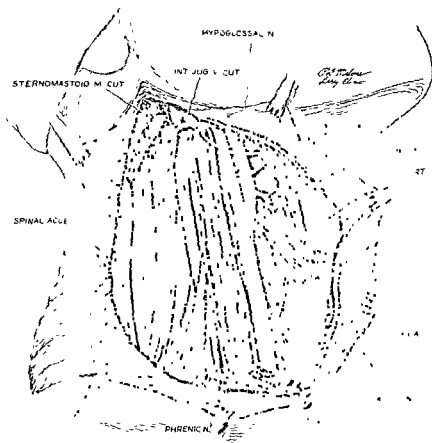


Fig. 217—The operation completed, the internal jugular ligated below and above, with the sternomastoid muscles severed below and above and removed

Note again in this dissection, with the operation completed, that the spinal accessory nerve is completely in view, the phrenic nerve on the outer edge of the scalenus anticus is exposed, the vagus nerve is freed from its sheath, the recurrent laryngeal nerve is visible up to its point of entrance into the larynx and the hypoglossal nerve throughout its tract. Note the inferior and superior thyroid arteries ligated and severed. The small thyroid gland has been completely removed up to the isthmus on the other side so that the trachea is completely bared.

removed half on the second day and half on the third day. The rubber dam is to remain in the neck for nearly a week since this is a large space and one does not wish to remove the drain until the skin flap has become well adherent to the underlying structures.

There is one point about which patients should be warned in connec-

tion with these radical dissections of the neck. It is impossible, we believe, to do these radical dissections of the neck, with complete removal of all possibly involved nodes in the regions beneath the angle of the jaw, without injuring the submaxillary branch of the facial nerve. This is the branch which, as everyone knows, supplies the depressor anguli oris on that side, and its injury results in the inability of the patient to pull down the corner of the mouth on that side when he smiles.



Fig. 218



Fig. 219

Fig. 218 —This photograph shows the neck of a patient upon whom a radical complete dissection for carcinoma of the thyroid involving the nodes was done, with removal of the internal jugular throughout its entire extent, the entire sternomastoid, all of the nodes and the entire thyroid up to the isthmus on the left and the left lobe of the thyroid.

Note the absence of shoulder drop and only moderate sinking in of the neck on the right side as compared with the left.

Fig. 219 —This photograph is that of a young girl who also had complete dissection of the left side of the neck, the removal of the entire internal jugular, sternomastoid muscle and thyroid gland together with the isthmus on the left side. Note that in spite of this radical dissection there is very little disfigurement, as seen in a comparison of both sides.

It has proved wise in our experience to warn patients and their friends beforehand of the occurrence of this moderate disfigurement so that they will not interpret the explanation for it after operation as an apology. We have stated simply that this is one of the prices they must pay to obtain the benefits of the radicalness of this operative procedure.

Patients who have had to have this operation have been, in many instances, greatly worried about the disfigurement. For that reason we have chosen at random, for illustrative purposes (Figs. 218 and 219) two patients who happened to come into the clinic at the time this article was being written, two young girls in whom these radical dissections had been done with complete removal of the sternomastoid, the internal

jugular, the thyroid gland on that side and exposure of all the nerve structures and fascial planes described in this operation.

One would expect that, as the result of the removal of the sternomastoid, the internal jugular and the thyroid, there would be an unsightly projection of the trachea and an unsightly sagging of the neck on that side. Such has not been the case, as can be seen in these illustrations. With preservation of all the nerve structures there has been no disability of any importance and the disfigurement has really been of a trivial character.

TECHNIC OF SUBTOTAL THYROIDECTOMY

FRANK H. LAHEY

In an experience with thyroidectomy now amounting to over 28,000 instances, it is inevitable that changes in our plan of the operation would occur from time to time. There have remained, however, basic principles which in my opinion cannot be violated if one wishes to obtain good results. Results may be called good only when the patient is completely relieved of the thyroid condition for which the operation was done, only when the mortality is kept, as it must be today with the antithyroid agents, well under 1 per cent and approaching that of zero, and only when morbidity, such as tetany and recurrent laryngeal paralysis, is largely absent.

Before discussing the technic of subtotal thyroidectomy, I would like to establish certain fundamental needs which I believe will be, perhaps not universally but quite generally, accepted by the majority of surgeons who have operated upon many patients for thyroid disease. The outstanding requirement for a good thyroidectomy, in my opinion, is good exposure. When one balances short incisions accompanied by attempts to remove thyroids without cutting the prethyroid muscle with the inevitable handicap which will come from the limitations of exposure related to these three factors in any large series of cases, namely, recurrent laryngeal paralysis, tetany and inadequate removals of thyroid tissue, the advantage of wide exposures with good-sized incisions and severed muscles will be convincingly demonstrated.

Skin Incisions.—In writing on this subject some years ago I devoted an entire paper to the matter of thyroid incisions, not only because they are important from the point of view of adequate exposure but because a conspicuous scar, in the minds of most women, means an unsuccessful outcome of the operation. It is just as easy to place an incision in a location where it is inconspicuous as it is to place it in a position where, because it cannot be concealed, it is always conspicuous. A goiter incision should have two features about it to be a good one: (1) It should be at a level where a string of beads placed about the neck will naturally rest at the junction of the neck with the chest. (2) It should have in it a gentle curve of such character, again, as to be concealed by a string of beads resting on the neck at the level where the neck joins the chest. There are some features which a goiter incision should not have, such as the following: It should not be a straight incision across the neck because that can never be made inconspicuous. It should not be of a horse-shoe type because the ends can never be concealed. It should never

be high on the neck because it will then always be obvious. It should never be out of balance, that is, with one end higher than the other, because it will then always be unsightly.

There have been many proposals that goiter incisions be measured by the width of a finger or by the width of two fingers above the sternal notch. This is an impractical method of determining the level at which goiter incisions should be made. It is impractical because of the fact that necks vary in length, that is, in the distance between the chin and the sternal notch. A level of one fingerbreadth above the sternal notch may be proper in one patient but improper in another.

Goiter incisions made free hand and judged by the eye will always be superior to those attempted by such mechanical means as measuring with fingerbreadths above the sternal notch.

We have practiced here the plan of marking proposed goiter incisions out with the back point of a knife which lightly scratches the skin and permits one to visualize where the incision will be and then correct improper levels, inadequate curves or lack of balance in the incision. In certain cases it is even of value to make the imprint of a point of a hemostat at either end of the limb of the incision and at a center point and then connect them by eye (Fig. 220). This has proved a very practical point in making incisions at proper levels, with proper curves and with good balance.

Elevation of the Skin Flaps.—Another point in goiter incisions is, in my opinion, the need to elevate the skin, subcutaneous fat and platysma in one layer. The easiest point at which to elevate the flaps is between the prethyroid muscles and the platysma (Fig. 221). This has the advantage of the lack of bleeding, and the particular advantage that it keeps the adipose layer of tissue between the skin and the platysma intact. If one elevates the skin flap in the adipose layer between skin and platysma, there will be two undesirable features: (1) prompt and marked reaction to trauma as evidenced by postoperative edema and (2) the development at times of numerous small connections between the skin and underlying prethyroid tissue which will produce unsightly puckering and dimpling as the patient swallows.

The above are but minor points in the elevation of the skin flaps for subtotal thyroidectomy. The all-important one is that the incision be of sufficient length to permit adequate elevation. An added 2 or 3 inches in a goiter incision that easily makes possible the exposure of the parathyroids and the recurrent laryngeal nerves, together with the other important anatomical structures, is a good investment. We believe that all skin incisions for thyroidectomy should expose the entire gland from its most inferior portion of its lower pole to the most superior portion of its upper pole and even a portion of the superior thyroid artery and

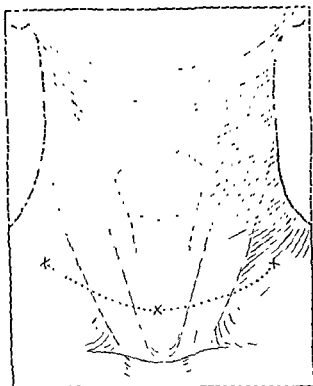


Fig 220.—Method of marking three points with the point of a hemostat along which the skin may be scratched with the back of a knife point to visualize the curve of the incision. This has proved valuable in our hands to visualize the planned incision so that if it is not satisfactory, corrections can be undertaken before the final incision is made.

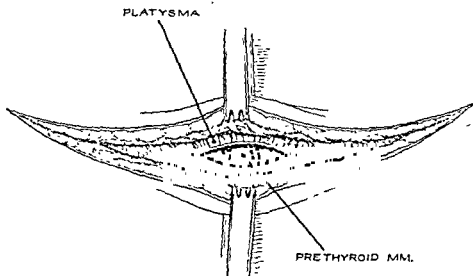


Fig 221.—Method of raising the skin flap by elevating it between the prethyroid muscles and the platysma. Note that when the platysma is raised this way the layer of adipose tissue between the skin and the platysma is preserved intact.

vein. There will be always a tendency on the part of surgeons to stop the elevation of the skin flap before it has been carried to an adequate

be visualized. As one observes in Figures 223 and 224 it becomes obvious that the important anatomy of the thyroid can be demonstrated only by the maneuver which I have stressed many times in writing upon this

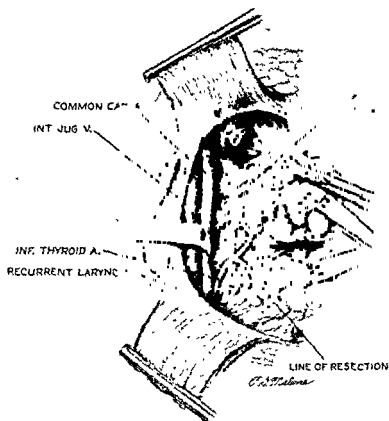


Fig. 223 — The veins running between the thyroid gland and the internal jugular vein are completely severed, the gland is lifted out of its bed, and the region between the trachea and the common carotid freed so that the inferior thyroid artery and the recurrent laryngeal nerve are exposed to view. In this illustration is shown a step which is not done until the lower pole has been mobilized, but for the purposes of demonstrating the most common position in which the upper parathyroid is found, the superior thyroid pole is shown here, demonstrated as severed.

Note in this illustration the recurrent laryngeal nerve running over the inferior thyroid artery. Note the relationship of the upper parathyroid and the recurrent laryngeal nerve as it enters the larynx in a position behind the larynx where it rests before the superior thyroid artery and vein are severed, and the upper pole mobilized away from the larynx and inward to expose the parathyroid.

subject, that is, the severing and ligating of the connections of the veins draining from the thyroid into the internal jugular. Whenever I see a thyroidectomy done without this technical step being completed, I know that one of two things will result. There will be a very bloody field be-

cause of the venous oozing or there will be only a severing of the top layer of the thyroid and that portion which rests in the groove between the common carotid and the trachea and the esophagus will be left behind—an inadequate subtotal thyroidectomy.

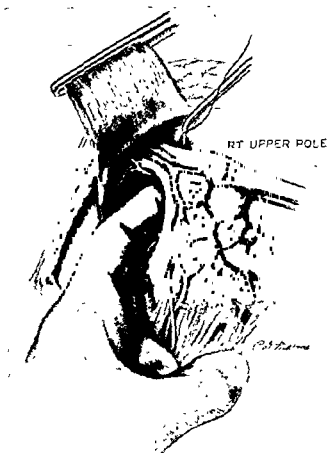


Fig 224.—Method of separating the upper pole of the thyroid from its attachment to the larynx so that the vessels can be completely freed and a ligature passed around them so that it does not include any of the apex of the upper thyroid pole. Note the fingertip placed beneath the upper pole to lift it away from the larynx.

This maneuver insures safe ligation of the superior thyroid artery and vein and, even more important, permits mobilization of the upper pole of the thyroid away from the larynx so that the parathyroid which rests against the larynx and behind this lobe can be exposed and preserved.

Demonstration and Isolation of Inferior Thyroid Artery.—With the common carotid and internal jugular retracted outward, the layer of tissue between these two vessels and the trachea and esophagus can then be gently opened by blunt dissection with scissors until the point is reached where the inferior thyroid artery can be visualized as it appears from behind the common carotid artery.

It is important to realize that the level at which the inferior thyroid

passed beneath these vessels, close to the trachea, they are grasped by two hemostats below and one hemostat above, and severed by a knife between the upper one and the lower two, leaving the hemostats behind to protect the trachea. Two hemostats, as shown in Figure 225, are

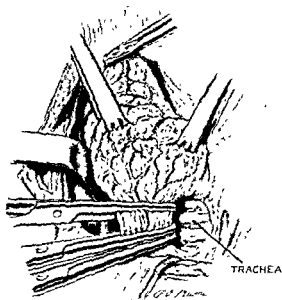


Fig. 225 — Method of grasping with hemostats the inferior thyroid vein and the occasional thyroidea ima artery as they enter the lower pole of the thyroid. Note that the trachea has been completely bared and, as shown in Figure 223, the recurrent laryngeal nerve has already been completely exposed so that there is no danger of including it in the clamps which cross the isthmus. Note in Figure 223 that the vessels running to the lower pole of the

behind, will be but a small remnant. Note in Figure 223 also that the upper pole of the thyroid with the superior thyroid is cut and pulled down and the lower pole up in order that the remaining remnant, marked by the dotted line labeled "line of resection," will be but a small one.

applied to the veins going to the isthmus in order that a tie may be placed about these veins running to the lower poles of the thyroid, one hemostat taken off, another tie again placed, and the remaining hemostat taken off. It has been our experience that when these veins running to the lower pole of the thyroid escape from a hemostat, retract behind the sternum and produce a hematoma, it is difficult to recover them

again satisfactorily because of the retrosternal hematoma. For that reason we believe the additional precaution of double clamping is well worth while. With the veins running to the isthmus tied below and above, the lower pole is then detached gently from the trachea and pulled upward, as shown in Figure 223.

Ligation and Severance of Superior Thyroid Vessels.—The next step in the thyroidectomy consists of grasping the upper pole of the thyroid (Fig. 222) and so pulling it to the inside that it can be separated from the point where it rests against the larynx so that the fibers of the inferior constrictor muscle can be well visualized. If the upper pole of the thyroid is pulled away from the larynx in this way, the blood supply consisting of the superior thyroid artery and vein can be clearly seen and ligatures placed about them by the special passer shown in Figure 254 which I devised a number of years ago and which we have since employed continuously. This permits the accurate passing of a No. 1 plain catgut tie about the pole so that it is possible to tie these vessels well off the thyroid gland itself. This is an important point because unless there is good exposure of the upper pole there will be occasional cases in which the tie includes a portion of the upper pole of the thyroid gland so that the knot cannot be shut down completely and there will be added danger of its being pushed off, resulting again in serious arterial hemorrhage postoperatively. Nothing which we have done has been of greater value to us in accurate control of the superior thyroid artery than ligation and religation of the thyroid gland under direct vision.

When one visualizes the anatomical situation in ligation of the superior thyroid artery, it is surprising that more hemorrhages do not occur following ligation and severance of this vessel. It is to be recalled that the superior thyroid artery is the first branch of the external carotid, that it is directly at the carotid bulb where there is a tremendous volume of blood thrust as it passes up the bulb into the internal and external carotids. If this artery is cut short, there will be a constant tendency, owing to the vigorous thrust which persists in the ligated stump, for the tie to be pushed off—a misfortune which has happened to us in the past on more than one occasion and was responsible for one serious post-operative emergency.

Mobilization of Upper Pole of Thyroid Downward.—With the superior thyroid vessels ligated and severed, the upper pole of the thyroid can now be turned downward and inward. This makes it possible to accomplish a radical removal of the thyroid. Without mobilization of the superior pole downward and inward, it will be possible to perform subtotal thyroidectomy only by leaving long strips of thyroid attached to the trachea and the larynx. By means of mobilizing the lower pole upward and inward and the upper pole downward and inward, the gland

can be so compressed that only small sections of thyroid will remain after subtotal thyroidectomy. To my mind, this has played an important part in increasing the radicalness of our subtotal thyroidectomies over the later years and so diminishing the incidence of postoperative persisting hyperthyroidism.

Identification of Superior Parathyroid.—With the upper vessels ligated and the upper pole turned down one should, with the aid of the Berens-Beebe loupe and good light, immediately begin the search for the superior parathyroid which is so constantly present behind the upper lobe of the thyroid as it rests against the larynx. So constant is the

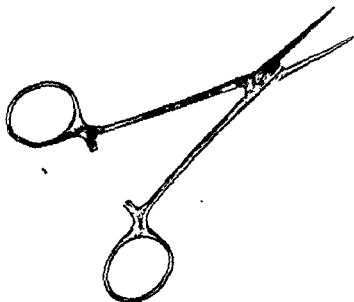


Fig 226 —Photograph of a hemostat with the jaws stamped from tip to heel in order to hold thyroid tissue throughout its extent

superior parathyroid in this position behind the larynx where it is protected by the upper pole resting against the side of the larynx that there will be only occasional cases in which it will not be possible to identify it and preserve it. We have now for a number of years insisted that every attempt be made to identify, demonstrate and preserve one parathyroid on each side when subtotal thyroidectomy is done.

Outlining Section of Thyroid to Be Removed.—With the upper pole pulled down and the lower pole pulled up, a line of hemostats is now inserted in the outer surface of the thyroid gland to mark out the portion which is to remain behind as the thyroid remnant upon which the patient will exist. We have developed over the years a special type of hemostat, as shown in Figure 226, in which the stampings run from the

point of the hemostat completely down to the place where they cross for the lock. These have been developed in order that they may hold throughout the course of the distances at which they are plunged into the thyroid gland and avoid pulling out at the heel of the thyroid which occurs with those hemostats in which the markings are only partly stamped down the jaws. With this line of hemostats introduced, an incision is made along this line in the downward direction, not in a transverse direction, to mark out the section of the thyroid which is to be removed (Fig. 223).

Resection of the Gland and Suture of Remnant to Trachea.—The isthmus is now grasped with double hooks and hemostats are gradually inserted between that structure and the trachea until the isthmus is mobilized from the trachea, which can readily be done with a very small amount of bleeding. As the isthmus is freed from the trachea, hemostats grasp the groove which was originally made in the body of the thyroid. These, as they are applied, are severed by scissors until the entire lobe is freed from the remnant which is to be left behind and the isthmus is entirely freed from its attachment to the trachea. As the isthmus is dissected its attachment to the left lobe is gradually clamped until the entire isthmus and that portion of the thyroid which is to be resected is entirely removed (Fig. 227).

It is to be recalled that at all times during the course of this procedure the recurrent laryngeal nerve is visible and one can be certain by frequently identifying it that it is not injured.

All vessels are now tied and it has been our custom never to tie multiple groups of hemostats but to tie each one individually in order that large segments of thyroid tissue shall not be tied in and thus endanger the blood supply to the parathyroids or cause injury to the recurrent laryngeal nerve.

If the line of incision in the body of the thyroid after the identifying hemostats have been inserted is made in an oblique and downward direction, when all of the blood vessels have been tied it will be found that the thyroid remnant remaining will fit well against the trachea to which it is then sutured, as shown in Figure 228. There has been nothing comparable with this plan which made it possible for us to perform subtotal thyroidectomy even in the case of very vascular hyperplastic glands before the days of antithyroid agents and still be able to close the wound without drainage.

We have employed double zero plain catgut sutures which are introduced to the edge of the thyroid remnant and then grasp the side of the larynx and the fascia over the trachea so that when the knots are tied the cut oozing surface of the severed thyroid is snugly placed against the trachea for control of bleeding (Fig. 228).

I do not wish to give the impression that this method of suture will control active, pulsating bleeders which must be tied, but it will control the oozing which will otherwise occur frequently from the cut surface of the thyroid.

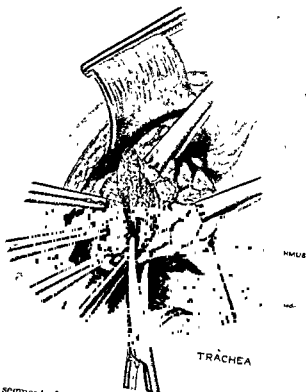


Fig 227 —The segment of thyroid into which the hemostats are plunged and which is to represent the segment of thyroid remaining is shown in the outer portion of the illustration. In the inner portion, the isthmus on the opposite side is shown as clamped, the isthmus has been completely separated from the trachea and the section of thyroid previously adherent to the trachea is being severed by scissors until the entire lobe on that side is completely freed.

With this portion of the operation completed, the entire right lobe of the thyroid except for the remnant which remains, together with the entire isthmus, is removed.

Left Subtotal Hemithyroidectomy.—With the completion of the right subtotal hemithyroidectomy, the left subtotal hemithyroidectomy is undertaken in the same way, again identifying the venous tributaries leading to the internal jugular vein, and the inferior thyroid artery, the recurrent laryngeal nerve, the isthmus, the vessels leading to the isthmus, the superior thyroid artery, and again mobilizing the upper pole from the larynx and identifying the parathyroid behind the upper pole as it rests against the larynx.

There is but one technical point to be added to the plan of left subtotal hemithyroidectomy as compared with the right. One must be careful as the isthmus is elevated off the trachea and as the subtotal thyroidectomy is conducted as described for the opposite side to be sure to identify pyramidal lobes, to follow them up to the point where they so often go, that is the level of the hyoid, and to remove them thoroughly.

I know of nothing which can produce greater disfigurement than leaving behind a pyramidal lobe which later becomes hypertrophied and sticks out on the neck like a thumb of tissue. It not only is a most dis-

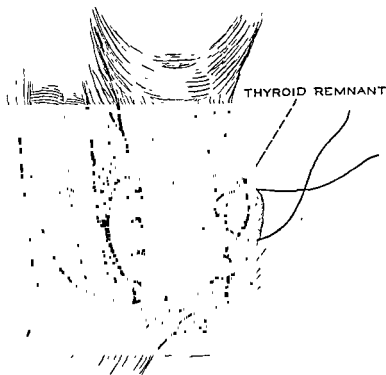


Fig. 228.—This illustration, as seen in other technical descriptions of subtotal thyroidectomy, shows the remnant of thyroid remaining which has been sutured against the trachea with 0 catgut stitches between the fascia covering the trachea and the edge of the thyroid so that the cut surface of the thyroid with all of its vessels tied is sutured against the trachea to control oozing.

figuring remnant but, as a result of the hyperplasia, sometimes causes recurrence of the hyperthyroidism.

Retying of Superior Thyroid Arteries.—With the subtotal thyroidectomy now completed on both sides, both superior thyroid arteries are again widely exposed and identified. Both are grasped with right angle clamps and are retied at a higher level than the original ligation with No. 2 plain catgut. This I would strongly urge upon everyone who is dealing with subtotal thyroidectomy. It is an additional precaution against the possibility of the original tie slipping off and it will give one

an added sense of confidence with regard to possible postoperative hemorrhages.

Closure of the Wound.—Closure of the neck requires little description. Prethyroid muscles are carefully sutured with No. 2 plain catgut, employing mattress sutures. Care should be taken not to include too wide ends and yet on the other hand to include enough of the cut ends of the muscle within the Ochsner clamp to hold the mattress sutures firmly. One must make absolutely certain that the large venous channels run-

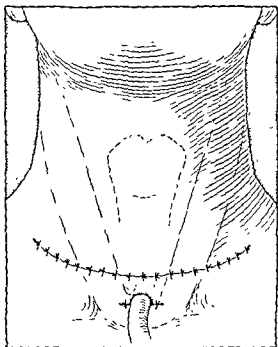


Fig 229 —The counter incision, first suggested by Kocher, through which it was the practice to bring a drain. This has two disadvantages (1) the counter incision in the skin can never be concealed and (2) the drain passes between the fibers of the prethyroid muscle so that when it is withdrawn the trachea becomes adherent to the skin and ascends and descends with swallowing.

ning on the prethyroid muscles are accurately controlled and great pains must be taken to inspect carefully all of the wound against the possibility of leaving behind bleeding points which will result in the accumulation of hematomas beneath the skin that will require reopening of the wound. This unfortunate complication will occasionally occur in spite of every precaution, but will occur less frequently if one takes great pains to control all of the vessels.

There have been many debates concerning whether or not the platysma should be sutured. We can only say that we have never sutured the

platysma. We believe that suture material placed in the platysma beneath the skin edge adds to wound complications. We do not believe that there is any danger of the platysma pulling the scar apart and we have obtained excellent wounds without the use of platysma sutures.

For many years we have closed wounds with Michel's skin clips. Good scars are obtained, their excellence depending on how painstakingly and accurately the skin edges are approximated.

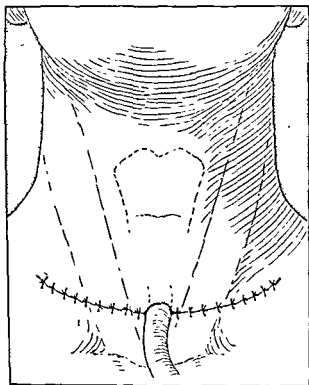


Fig 230.—This incision in which the drain is brought out through the central portion of the wound does not have the disadvantage of a disfiguring counter incision but does have the disadvantage of the skin becoming adherent to the trachea where the drain has been passed between the two sets of fibers of the prethyroid muscle so that it becomes adherent to the skin and ascends and descends with swallowing.

If one leaves skin clips on longer than three days, there will be unsightly pinprick holes and for that reason half of the clips are taken out on the second day and the other half on the third day. There will never be any danger of the wound pulling apart, because even if the patient were to vomit or raise his chin, the pull will be not on the skin but on the sutured prethyroid muscles and will cause him to stop the movement immediately.

Use of Drains.—While we have closed almost all of our thyroidectomies without drainage, there have been occasional cases in which, because of undesirable oozing or because large adenomas have been re-

moved, drainage was necessary. I would like to urge two or three points in respect to drainage. One should never make the counterincision as shown in Figure 229, which was suggested by Kocher, because this will produce a scar that can never be covered. One should never bring a drain out to the middle portion of the wound (Fig. 230); this will require it to be brought out between the prethyroid muscles and when the drain is removed the skin will become adherent to the trachea by scar tissue so that it will ascend and descend in an undesirable way upon swallowing.

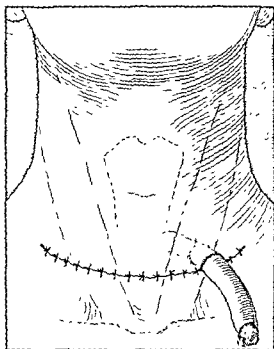


Fig. 231 —Method of introducing the drain through the fibers of the sternomastoid and bringing it out through the corner of the wound. This permits complete closure of all of the prethyroid muscles in the middle line and interposes a layer of muscle between skin and trachea so that the latter does not become adherent to the skin and produce the unfortunate bobbing up and down as the patient swallows.

In Figure 231 is shown the method that we employ in the use of drains. The drain is brought out through the belly of the sternomastoid muscle and to the outer angle of the wound. This results in sutured muscle being interposed between the entire skin flap and the trachea. When the drain is withdrawn, the aperture through the sternomastoid will close and adhesions will not be established between the skin scar and the trachea. Thus the disfigurement and undesirable bobbing up and down of the skin upon swallowing, which occurs when drains are placed in the wound in other positions than that shown in Figure 231, will not result.

MENINGIOMAS AND NEUROFIBROMAS OF THE SPINAL CORD

Certain Clinical Features and End Results

GILBERT HORRAX, JAMES L. POPPEN, W. Q. WU AND P. R. WEADON

The purpose of this communication is to present the experiences of the neurosurgical department of the Lahey Clinic in dealing with the benign, encapsulated tumors of the spinal cord during the past fourteen years. These tumors are the extramedullary, intradural meningiomas and neurofibromas (neurolemmomas) arising respectively from the meninges or from a spinal nerve root.

The first time that such a tumor was localized and removed operatively was on June 9, 1887.⁵ The localization was made by Sir William Gowers, and the tumor was removed by Victor Horsley. The patient was completely cured. Since that date many individual case reports as well as reports of series of cases have been made, and the end results on the whole have been extremely favorable.^{1-4,6} Indeed, the results have often been dramatic, inasmuch as many individuals have recovered completely from paralysis of the lower extremities and have been relieved entirely of the severe pain which they were experiencing before the growth was removed.

The symptomatology of the tumors in question is too well known and has been so frequently discussed that it is not our purpose to dwell on this aspect in any detail. Suffice to say that pain following the course of a spinal nerve root is one of the prominent and early symptoms in a large number of patients, followed at varying intervals—weeks to years—by signs of spinal cord compression, paresthesia, increasing weakness of one or more extremities, and eventually paraplegia with bowel and bladder incontinence if the tumor is not recognized and extirpated.

The material from which the present data were derived was taken from the records of 60 patients from whom 61 tumors were removed and verified microscopically (1 patient had 2 tumors). The patients were observed between January 1, 1933, and November 25, 1947, the observation therefore varying from one to fourteen years. During this same period there were 157 spinal cord tumors of all types verified on the neurosurgical service, so that the meningiomas and neurofibromas represent 38.8 per cent of all the spinal tumors seen on the service.

Of the 61 tumors with which we are concerned, 37 or roughly 60 per cent were neurofibromas and 24 or roughly 40 per cent were meningiomas. The various levels at which the two types were found in the cord are interesting. The thoracic region was the most frequent site for both

varieties, a total of 35 tumors, roughly 57 per cent, being located in this area, but whereas 18 or 48 per cent of neurofibromas were so situated, 17 or 70 per cent of the meningiomas involved the thoracic cord. The next most common site for neurofibromas was in the lumbar area, where there were 13, in contrast to one meningioma, and there were 6 of each tumor type in the cervical region.

The sex and age incidence in our group follows that reported by others. There were 20 males (2 tumors in one individual) and 40 females. The ages of the patients varied from 18 to 71 years.

The average duration of symptoms before operation was twenty-three months. There were 22 patients who had had symptoms for less than one year, whereas in 32 the symptoms had been present from one to five years. In 6 patients the duration was not given exactly.

MYELOGRAPHY

In addition to the history, neurologic examination and the usual lumbar puncture studies, it was deemed wise to do some form of a myelogram on 55 patients in order to localize the tumor with more exactness. For this purpose oxygen was used thirty times, lipiodol eighteen and pantopaque seven.

RESULTS

Of the total 60 patients, 44 or 73.3 per cent were either completely cured or so greatly improved that they were capable and useful citizens. Twelve others (20 per cent of the total) were somewhat improved over their preoperative condition, while 3 or 5 per cent were unimproved. There was one death in the series (a patient with recurrent tumor operated on elsewhere eight years previously), giving an operative mortality of 1.7 per cent.

It is of particular interest to compare the results of operation as correlated with the duration and the severity of the patients' symptoms.

1. *Symptoms for less than one year.* Among the 22 patients who had symptoms for twelve months or less, 9 had severe pain or weakness up to paralysis. Of these, 7 or 77 per cent (31 per cent of the 22) were cured or greatly improved, one was somewhat improved and one was unimproved. Of the other 13 who had only slight pain or weakness, 12 or 92 per cent (54 per cent of the 22) were cured or greatly improved and one was somewhat improved. Thus 85 per cent of all the patients in this group were cured or greatly improved.

2. *Symptoms for one to five years.* Here the story is quite different. There were 32 patients in this group. Ten of these had severe pain or weakness up to paralysis and none of them was cured or greatly improved. Eight were somewhat improved and 2 were unimproved. Twen-

ty-two of the 32 patients with long duration of symptoms had only slight or moderate pain or weakness. Of this number, 20 or 90.9 per cent (62.5 per cent of the 32) were cured or greatly improved, and 2 were somewhat improved.

It would seem to be a fair deduction from all these figures, therefore, that if a patient with the type of spinal cord tumor under discussion has only slight or moderate symptoms, he has a 90 per cent chance of being cured or greatly relieved by the removal of his growth no matter how long his symptoms may have been present. Furthermore, 75 per cent of those with severe symptoms, if these have been present less than one year, should be very greatly relieved, whereas if these severe symptoms have continued for one to five years their chances of great relief are extremely small, although even then some improvement may be expected.

OPERATIVE PROCEDURES

There are a few points which should be emphasized concerning the operative removal of extramedullary spinal cord tumors. For this purpose we may consider the neurofibromas situated (a) on the posterior surface of the cord, (b) lateral to the cord and (c) anterior to, that is underneath, the cord, and secondly the meningiomas which are attached to the dura, particularly along the lateral wall of the spinal canal.

For all tumors of the types here considered, after they have been localized by neurologic measures combined with myelography when necessary, we believe that a complete laminectomy should be performed covering the area in question. As a rule this will mean the removal of the spines and laminae of about four vertebrae in order to get adequate exposure above and below the growth. Although some tumors are doubtless capable of removal using only a hemilaminectomy, we believe that there is less danger of cord damage by taking off the laminae over both sides, and we have never seen any disability attributable to the bilateral procedure.

The bone having been removed by rongeurs in the usual way and the ligamentum flavum as well as the layer of fat over the dura likewise excised, the tumor may often be felt as a firm area by palpation of the dura if the growth lies on the posterior or posterolateral surface of the cord. There is also increased vascularity of the bone and of the dura at the level of the tumor, especially with meningiomas. The dura should now be opened by a median linear incision, and the edges of dura are conveniently held retracted by taking a few silk sutures through the dura and carrying the stitch out through the retracted muscle, tying the silk so that the dura is held firmly reflected. As the dura is being opened it will be seen to be somewhat adherent to the surface of the tumor,

from which it must be carefully separated. It will likewise be seen that there is little or no pulsation of the cord below the growth, whereas normal pulsation is present above it.

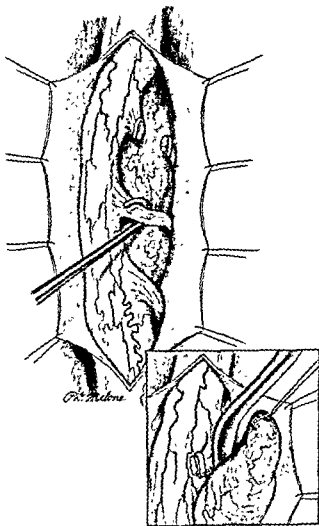


Fig. 232.—Neurofibroma lateral to the cord. *Inset*, the upper end of the tumor lifted by traction sutures passed through it and the capsule freed from the cord by a smooth blunt dissector. One nerve root has been divided.

When a neurofibroma lies on the dorsal surface of the cord the problem of its removal is relatively simple. The delicate arachnoid membrane is easily dissected away from the growth after which it may be mobilized by lifting up one of its ends with a suitable instrument and carefully separating it from the cord to which it is only slightly adherent. A nerve root will be seen to enter the tumor at some point and this root from

which the growth arises should be divided between silver clips, silk ligatures or after crushing the root with a hemostat.

If the neurofibroma lies lateral to the cord and is not large enough to have compressed the cord greatly it may often be "delivered" after freeing the arachnoid over it by lifting one end with a blunt dissector or by passing one or two silk stitches through the end and using these to make traction on the tumor (Fig. 232). Great care should be exercised, of course, not to let the growth make any added compression of the cord



Fig. 233 — Neurofibroma lying largely underneath (anterior) to the cord. *Inset*, the capsule of the tumor has been incised and its contents evacuated by spoon or curet. The capsule may then be withdrawn without further compression or damage to the cord.

during delivery, and if there is any question of this, especially if the tumor is plump rather than elongated, its contents should first be removed by curettage, after which the capsule may be withdrawn and gently separated from the cord and neighboring nerves. In all cases the nerve root from which the growth has arisen must be sacrificed, but even in the cervical or lumbar region this leaves only a minor sensory deficit, which in any case was doubtless present before operation.

In rare instances when the tumor lies largely or wholly underneath

(anterior) to the spinal cord its edge must be exposed by gentle retraction and then its contents must be very completely evacuated by blunt or sharp curets according to how soft or fibrous the growth happens to be. The capsule is then withdrawn without further contusion or compression of the cord (Fig 233) Some tumors will be seen to extend far out into or through an intervertebral foramen, and of course in this case they must be followed out as far as necessary to complete their removal. There are

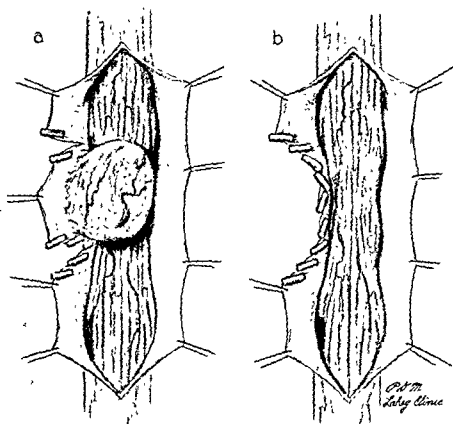


Fig 234 — Meningioma with its attachment to the dura lateral to the cord (a). This dural attachment must be excised with the tumor. Silver clips are placed along the vascular edges as the dura is incised (a, b)

occasional cases of "dumbbell" tumors in the thoracic region, one portion of neurofibroma being inside the spinal canal compressing the cord, and the other portion extending through an intervertebral foramen into the chest where it may attain large size. The intrathoracic portion must be removed by a secondary operation from an appropriate approach through the chest.

Meningiomas which involve the cord by pressure arise from the con-

liguous dura. Their operative removal in large measure follows the methods described for neurofibromas except that in addition to removing the tumor itself, its dural attachment must likewise be excised inasmuch as it contains tumor cells. This is accomplished by incising the dura above and below the tumor and carrying the incision completely around the attachment (Fig. 234). This offers difficulties on account of vascularity but silver clips may be placed along the edges as they are cut, or bleeding may be controlled by careful electrocoagulation, avoiding the use of the electric current when the dissection is too near the cord or spinal nerve roots. The dural defect should be covered with gelfoam.

After the removal of spinal tumors the cord over the whole area exposed should be covered with a thin layer of gelfoam and the dura closed with interrupted silk sutures about a quarter of an inch apart. The muscles should then be closed with through-and-through stitches of heavy silk or silver wire after which several further layers of interrupted sutures of fine silk should be taken in the fascial layers and in the skin without drainage.

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THE TECHNIC OF LUMBAR SYMPATHECTOMY

JAMES L. POPPEN

Surgery of the sympathetic nervous system has been gathering momentum over the past few years, with varying results. As is true of many relatively recent types of surgery, lumbar sympathectomies have been carried out unnecessarily in some instances. In doing so, however, reasonably clear cut indications and contraindications have evolved. That the operation is of great merit in well selected cases cannot be over-emphasized. Many lower extremities have been saved by timely lumbar sympathectomy.

The indications for lumbar sympathectomy are mainly peripheral vascular diseases such as thrombo-angiitis obliterans (Buerger's disease), Raynaud's disease, arterial embolism, arteriosclerosis, livedo reticularis, chronic ulcers, causalgia, hyperhidrosis and traumatic sympathetic reflex dystrophy. The decision as to whether sympathectomy should be carried out in a given individual can usually be determined by adequate preoperative studies, especially by a temporary interruption of the lumbar sympathetic pathways with a well directed procaine block. By this means a reasonably accurate knowledge can be obtained as to the efficacy of lumbar sympathectomy. Unfortunately, temporary procaine block cannot be relied on completely. This is especially true in the advanced cases of Buerger's disease and arteriosclerosis. In many of these patients there may be an element of associated arterial spasticity which is not determined by temporary procaine block. In Buerger's disease and arteriosclerosis more information may be gained by subjecting the extremities to cold atmosphere; if the temperature in the extremity does not fall within a reasonable length of time, sympathectomy, in all probability, will not be of help. In several instances the lumbar sympathetic block did not result in a rise in the skin temperature of the extremity; however, by permanent interruption of lumbar sympathetic pathways, a rise in temperature can readily be measured as well as an increase in circulation demonstrated by pulsation in a peripheral vessel which was pulseless before operation. If pain in the lower extremity, caused by peripheral vascular disease, is not relieved by a procaine block, one can be reasonably certain that relief will not be obtained by sympathectomy. It is equally true that relief of ischemic pain is not always obtained by operation even though a satisfactory relief seemed assured by temporary procaine sympathetic block.

I believe that sympathectomy in erythromelalgia should be discouraged in all cases. Certainly in my experience patients have com-

plained more bitterly of burning discomfort after operation than before the sympathectomy.

Since lumbar sympathectomy can now be performed in a few minutes, necessitating only a short hospital stay, it is justifiable to institute the procedure in certain patients with advanced arterial disease in whom the results of preoperative tests have been questionable. It is important in all patients with advanced disease to perform an adequate sympathectomy. In all patients who have Buerger's disease or arteriosclerosis in whom the operation is performed, the first, second and third lumbar ganglions should be removed, preferably including the twelfth thoracic. It is equally important to perform a minimal sympathectomy in cases of hyperhidrosis in which the upper as well as the lower extremities are involved. The disagreeable excessive perspiration that results in patients who have had an upper thoracic and a lumbar sympathectomy may be avoided to a great degree by removing only the fourth lumbar ganglion on each side.

Spinal anesthesia is the anesthesia of choice for lumbar sympathectomy. The position of the patient is especially important. I prefer to have the patient in a slightly oblique position, as indicated in Figure 235, *a*. A small skin incision, 3 to 4 inches long, is made corresponding approximately to the course of the muscle fibers of the external oblique, the incision extending from the tip of the tenth rib. The fibers of the external oblique muscles are separated and kept retracted with a small sella retractor. The internal oblique muscle fibers are then separated, as well as the transversalis. Care must be taken in splitting the transversalis muscle that the peritoneum is left intact. The peritoneum is usually retracted by inserting the index and middle fingers through the muscle splitting incision and exerting pressure with the palmar surfaces of those fingers against the parietal surface of the transversalis muscle laterally. The line of cleavage can readily be followed, sliding gently over the inner surface of the quadratus lumborum muscle to the lateral margin of the psoas major muscle. The fingers are then elevated following the contour of the psoas muscle medially. The palmar surfaces of the two fingers lie on the belly of the psoas major muscle, with the peritoneum and its contents displaced medially. Considerable manipulation may be eliminated by inserting a portion of a dental roll attached to a black silk string with a long forceps to the site where the palmar surfaces of the index and middle fingers are firmly kept in contact with the belly of the psoas major muscle. The fingers are removed from the site and the cotton roll kept in contact with the muscle or the forceps. A Grant bladder retractor is inserted, sliding it gently along the forceps to the point where the cotton roll is held on the psoas major. This maneuver allows the peritoneum to be retracted medially so that the psoas muscles can

be readily visualized. By gentle retraction medially with the Grant bladder retractor, the line of reflection of the peritoneum will fold on itself, forming a small white line. This is incised, allowing one to enter the proper line of cleavage. The soft tissues are retracted medially to the lateral portion of the bodies of the lumbar vertebrae (Fig. 235, *b*). The lumbar sympathetic chain and ganglions can be readily seen lying in the gutter that is formed by the rounded portion of the bodies of the verte-

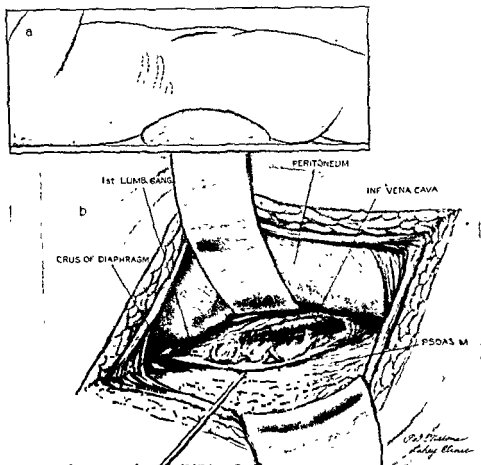


Fig. 235.—*a*, Position of the patient and the approximate site of the incision *b*, Retraction of the soft tissues medially and anteriorly; also the crus of the diaphragm incised

brae and the psoas minor muscle. The line of cleavage is followed cephalad well above the crus of the diaphragm. The latter is split sagittally, allowing the twelfth thoracic ganglion to be removed if found indicated.

The removal of the sympathetic trunk and the dissection will be greatly facilitated if the rami are divided before either end of the lumbar chain is divided. The sympathetic chain rarely lies beneath the lumbar vessels on the left side; on the right side it occurs quite frequently.

The vena cava many times lies over the sympathetic trunk on the right side (Fig. 236); however, it can be gently retracted and the only time

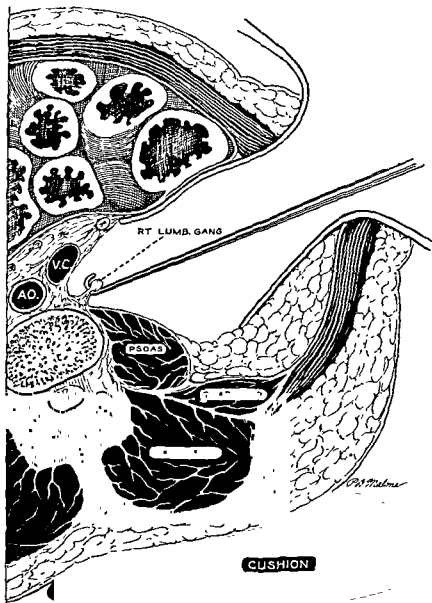


Fig. 236—Relationship of the anatomical structures to the lumbar sympathetic chain through a cephalad transverse section.

that I have found it to be a handicap was during a second operation at which time it may be firmly plastered down by adhesions over the sympathetic trunk.

There should be absolutely no question in the surgeon's mind as to whether the structure is sympathetic trunk or not, even though at times on the right side he may find a fairly long trunk with no intervening ganglion. In those instances a fusion of two ganglions above or below is always found. Certainly, one should never confuse a lymphatic node with a sympathetic ganglion. In the first place they are of entirely different color and if the line of cleavage is properly obtained, the lymph nodes will be retracted away from the sympathetic trunk and therefore give no trouble. The genitofemoral nerve must not be confused with the sympathetic trunk.

It is of importance to the patient that local exploration by palpation be performed during every sympathectomy. The lower pole of the kidney can always be felt. At times a hypernephroma or other condition may be noted. Either the descending or ascending colon can readily be palpated for masses.

The incision is closed with a few black silk sutures. The patient may be allowed up the following day.

The complications of the procedure are minimal. It is of great importance, however, that the patient be informed, if he is a male, that there may be a change in the sexual function. The execution of intercourse will be completely normal except that there will be a dry ejaculation in about 50 per cent of patients. In those patients, of course, sterility is inevitable. However, it in no way interferes with the act of intercourse. We have found no sexual change in the female.

TECHNIC OF EXPOSING THE FACIAL NERVE AS AN AID TO SURGERY OF THE PAROTID GLAND

FRANK D. LATHROP

Surgery of the parotid gland, particularly with respect to the excision of tumors, is associated with the inherent danger of injury to the facial nerve. The psychologic effect of a complete unilateral paralysis of the face upon the patient and, to a lesser extent, upon the surgeon is of such a calamitous nature that every effort should be made to prevent its occurrence in so far as is commensurate with adequate surgery.

It has long been a maxim of Dr. Lahey, when performing thyroid surgery, to isolate and expose the inferior laryngeal nerves in order to prevent permanent paralysis of a vocal cord. Application of this principle to surgical procedures on the parotid gland would insure the integrity of the facial nerve when it is not directly involved by a pathologic process. While perhaps not necessary or advisable when the tumor is small and peripherally located, observance of this aphorism when the tumor is large or deeply situated will reduce to a minimum the dangers of a permanent facial palsy and facilitate the adequate surgical removal of the neoplasm. The latter is of primary importance if the incidence of recurrence is to be decreased.

ANATOMY

The facial nerve makes its exit from the skull through the stylomastoid foramen medial to the tip of the mastoid process. From this point the nerve courses antero-inferiorly and somewhat laterally to enter the parotid gland with which it is intimately related. In the majority of instances the parotid gland is composed of a large superficial lobe and a smaller deep lobe connected by an isthmus between which the facial nerve is situated. Shortly after entering the posterior border of the gland the nerve divides into its two principal components, the temporofacial and cervicofacial divisions, which lie on either side of the isthmus connecting the two lobes of the parotid gland.

The temporofacial and cervicofacial divisions continue to run forward and divide between the lobes of the gland to appear along the anterior border of the superficial lobe. These secondary branches further divide and fan out in the soft tissue of the face to supply the musculature in the temporal, zygomatic, buccal, mandibular and cervical areas.

In its course through the soft tissue of the face, the facial nerve is closely associated with structures which are of aid in determining its location. The relationship of these landmarks to the nerve, while varying

of the operation it is important that the anterior wall of the external auditory canal be closely "hugged" while freeing the posterior border of the gland from the external auditory canal and that the dissection be directed slightly inferiorly while the parotid gland is retracted forward with a narrow-bladed retractor such as the "pole" retractor used in thyroid surgery in order that the base of the styloid process may most easily be located. Once the base of the styloid process is visualized the dissection is carried along the lateral surface of the styloid process until the facial nerve is encountered (Fig. 237). Isolation of the nerve is facilitated by the use of a nerve stimulator delivering faradic current at minimal intensity. Proper use of a nerve stimulator permits the operator to distinguish the facial nerve readily from the tendons and fibrous tissue

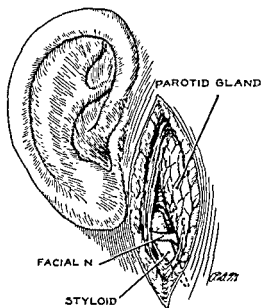


Fig 237.—Relationship of facial nerve to styloid process

bands situated in this region. Once the facial nerve is located and isolated proximal to the posterior border of the parotid gland, it may be traced forward through the gland by sharp and blunt dissection and retracted out of harm's way while the parotid neoplasm is removed with minimal danger of incurring a permanent facial palsy.

While this method of segregating the facial nerve is relatively simple when the parotid tumor is small, its accomplishment is difficult when the neoplasm involving the parotid gland is large. In the latter case the facial nerve is more easily exposed anterior to the parotid gland.

Distal to the parotid gland the temporofacial and cervicofacial divisions of the facial nerve continue to decussate and form a fan-shaped network of small nerves nestled in the adipose and muscular tissues of

the face. While these branches are small, it is not impractical to locate one or more of the branches and, thereafter, trace it backward to the principal division of the facial nerve from which it arose in order that permanent damage to the facial nerve might be avoided.

The buccal branch of the facial nerve distal to the parotid gland maintains a close relationship to the parotid duct. If the anterior border of the parotid gland is exposed through the previously described incision,

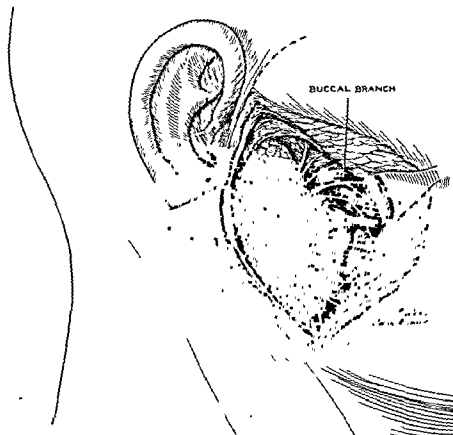


Fig 238 —Relationship of buccal branch of facial nerve to parotid duct

this branch of the facial nerve may be located as it runs slightly superior and parallel to the parotid duct. The latter is a relatively large, thin-walled, flat, tubular structure coursing anteriorly across the masseter and buccinator muscles from approximately the midpoint of the anterior border of the parotid gland toward the upper lip, and is readily recognized. Careful search of the adipose tissue lying on the facial musculature in the area just superior to the parotid duct and slightly anterior to the anterior border of the parotid gland enables the operator to expose

the buccal branch of the facial nerve (Fig. 238). Its exposure in this location is facilitated by employing the nerve stimulator and small, blunt, curved eye scissors. The former permits accurate differentiation of nerve and the numerous small blood vessels of approximately the same caliber which abound in this region, while the latter, when repeatedly inserted into the adipose tissue with the blades closed and gently opened in such a manner as to "cross-hatch" a given area, effectively frees the buccal branch from the surrounding soft tissue and permits its accurate identification with the nerve stimulator.

Once the buccal branch of the facial nerve has been located distal to the anterior border of the parotid gland in this manner, it can be traced backward underneath the anterior border of the gland. From this point the anterior border of the superficial lobe of the parotid gland may be elevated superiorly and inferiorly to expose the remaining branches of the facial nerve. With branches of the nerve kept in constant view by retraction of the superficial lobe of the gland, the dissection is carried posteriorly until the converging branches unite, to continue proximally as the cervical trunk. Transection of the isthmus of the gland parallel to the facial nerve permits removal of the superficial lobe of the parotid gland together with, in the majority of instances, the parotid neoplasm. In the event the parotid tumor involves the smaller deep lobe of the parotid gland also, it may be removed in its entirety by gentle appropriate retraction of the facial nerve away from the field of immediate dissection. In either case, since the facial nerve is visualized from the cervical trunk to its facial arborization, the possibility of a permanent paralysis of the facial nerve is minimized.

SUMMARY

The surgical anatomy of the facial nerve in its extracranial course and the relationship it bears to the parotid gland have been described. Specific landmarks with which the course of the facial nerve is commonly associated have been discussed, as well as their value in ascertaining its location.

Methods for exposing the facial nerve with respect to the parotid gland have been given. Thorough familiarity with these methods will permit exposure of the facial nerve and, as a consequence, will facilitate the adequate surgical removal of the pathologic process within the parotid gland and minimize the danger of a permanent facial paralysis.

CARCINOMA OF THE EPIGLOTTIS TREATED BY SURGICAL EXCISION WITH OPERATIVE TECHNIC

WALTER B. HOOVER

The epiglottis, an appendage of the larynx, may be the primary site of a carcinoma of varying grades of malignancy. Fortunately, this appendage may be totally removed. If a carcinoma of small size is present on the epiglottis, no matter what grade of malignancy, if it is believed to be confined to the epiglottis, removal of the lesion on the epiglottis with an adequate free margin of normal tissue is indicated. Following the removal the margins should be checked microscopically by the pathologist to ascertain whether or not removal has been adequate.

It is a well recognized fact that the surgical treatment of carcinoma should remove the lesion with an adequate margin of normal tissue in order to insure the complete removal of the carcinoma. The magnitude of the operative procedure depends upon the size of the lesion, the presence or absence of demonstrable metastases in the regional lymph nodes and the organ or organs affected. It is also well recognized that carcinomas of all grades metastasize and the size of the initial lesion does not indicate whether or not metastases have taken place. There is marked variation in the character of carcinomas. Usually, carcinomas of the higher grade by Broder's classification metastasize earlier and more extensively. A small tumor of Grade III or IV may have metastases that are much larger than the initial lesion and it is also true that a tumor of Grade I or II may grow to be of considerable size without demonstrable metastases. Surgical excision of the lower grade carcinomas gives a higher percentage of cures.

It has been my experience that the complete removal of the epiglottis, including the aryepiglottic fold, the lateral pharyngo-epiglottic fold and even a portion of the false vocal cords (ventricular bands), can be carried out without serious disturbance in the function of the larynx. The opinion has been expressed that it is necessary to retain the base of the epiglottis for adequate laryngeal function. However, Tucker has described the removal of the entire epiglottis for carcinoma and New, in a discussion of Broyles' paper and in a symposium on cancer, has described his treatment of cancer of the epiglottis. I wish again to emphasize the fact that the tissues of the anterior portion of the larynx from the true vocal cords upward, taking the entire epiglottis and the tissues of the pre-epiglottic space along with the aryepiglottic fold, a portion of the false cords (ventricular bands) and the lateral pharyngo-epiglottic folds, have been removed without seriously interfering

a nonexplosive mixture and may well be a combination of intravenous pentothal and nitrous oxide-oxygen inhalation. The patient is draped as for the usual laryngofissure or thyroid operation. A median line incision is made from the level of the hyoid bone to the level of the cricoid cartilage (Fig. 239, a). The dissection bares the hyoid bone, the thyrohyoid membrane, the thyroid cartilage and the cricoid cartilage in the median line. All bleeding is controlled. A second incision is made as for the usual tracheotomy or the initial incision may be extended to expose the upper three rings of the trachea. The thyroid isthmus may be separated and tied if it is in the way. Again, all bleeding is controlled. An opening is cut in the trachea and the flexible endotracheal tube with balloon cuff is inserted into the tracheal opening and inflated. The endotracheal tube is connected with the nonexplosive nitrous oxide-oxygen mixture (Fig. 239, b).

The next step is the opening of the larynx in the median line. The thyroid cartilage is tested for firmness. If it cannot be cut through with a knife, a saw is used to make a groove in the midline through the thickness of the cartilage. The thyrocricoid membrane is pierced in the midline above the cricoid ring with the electrosurgical needle with a blended cutting and coagulation current and is carried upward in the median line between the anterior attachment of the true vocal cords. A self-retaining retractor of the mastoid type is then placed between the cut edges of the thyroid cartilage and separated.

At this point a pack may be placed in the upper end of the trachea to guard further against the aspiration of blood into the bronchial tree. The base and a considerable portion of the epiglottis can be visualized. After the anterior attachments of the true vocal cords have been reached, the incision no longer need remain in the midline but is directed laterally and upward on each side. If there is any question as to the growth nearing the anterior attachment of the false cord, a portion of the thyroid cartilage above the attachment of the true cords may also be removed and the incision is then extended laterally and upward, that is, lateral to the cartilage of the epiglottis to both the right and left, giving a Y-shaped incision. As this incision is extended (Fig. 240, a) the larynx can be spread open more widely, giving excellent exposure. Any bleeding point may be electrocoagulated, or the vessel caught and tied or sutured. As the incisions are extended, the base of the epiglottis may be retracted downward with the tissues of the pre-epiglottic space and also removed with the epiglottis. With the base of the epiglottis and its lateral attachments freed, the pre-epiglottic tissues are detached from the hyoid bone. The free tip of the epiglottis, which extends to the base of the tongue, is then caught with a tenaculum and retracted (Fig. 240, b).

The attachment to the base of the tongue is clamped and cut free, and the entire epiglottis removed.

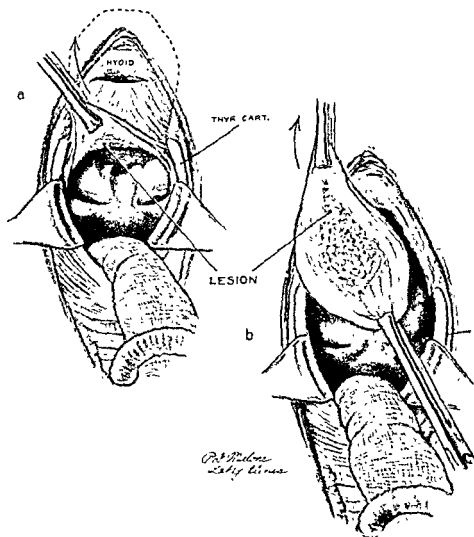


Fig. 240 —*a*, The thyroid cartilage is retracted and the incision extended upward on each side of the epiglottis. A tenaculum has been placed in the base of the epiglottis and the dissection of the pre-epiglottic space begun.

b, The free tip of the epiglottis has been caught with a tenaculum and pulled down, inverting and everting the epiglottis, in which position it is cut free from the hyoid and the base of the tongue.

Following complete control of bleeding, the wound is closed by suturing the mucous membrane of the base of the tongue as near the hyoid as it will reach and by suturing the mucous membrane of the false cords and lateral walls of the pharynx over the denuded area so far as it

will reach. This leaves a considerable area of denuded tissue which will heal in the same manner as a tonsillar fossa. If a Levin tube for feeding purposes was not passed before the anesthesia was begun, it may be inserted before closure of the laryngofissure. The packing is removed from the upper end of the trachea. The pharynx is kept clear of secretions by the application of suction. The muscle and fascia are closed by interrupted fine chromic catgut sutures, the subcutaneous tissue with fine plain catgut and the skin with silk or dermol. The balloon cuff of the endotracheal tube in the trachea is deflated and the tube withdrawn, suction is applied to the tracheobronchial tree and a tracheotomy tube (No. 5 or 6) is inserted. A snug dressing is applied with an elastic bandage to the area of the larynx.

POSTOPERATIVE COURSE

At the time of operation and following the surgical procedure, antibiotics are given. The Levin tube is left open for aspiration and intravenous fluids are given for the first twenty-four hours. At the end of this period tube feeding is begun. By the fifth day the tracheotomy tube, as a rule, can be plugged and the patient is able to breathe through the larynx. The snug dressing is kept over the incision, the sutures being removed about the fifth day and the dressing about the eighth day. The use of a pressure dressing prevents the blowing of secretions and foreign material into the wound on coughing or swallowing. Healing is quite rapid. Swallowing is allowed on the eighth or ninth day and if no difficulty ensues from leakage into the trachea the Levin tube is removed. Most patients can be discharged from the hospital about the tenth to the twelfth postoperative day.

REPORT OF CASES

Table 1 summarizes the data on 5 patients who have been operated on since October 1, 1945. All of these patients were males. As a possible etiologic factor, 3 were very heavy smokers; the other 2 smoked more than average. The youngest was 49 and the oldest 65 years of age. Symptoms referable to the throat had been present from one month to three years previous to operation. The complaints were pain in the throat in 3 cases, hoarseness in 3 cases, dysphagia in 2, dyspnea in 1 case and weight loss in 1. None of the patients had syphilis.

One patient did not have previous treatment before coming to the clinic. The other 4 patients had treatments, 3 by their local nose and throat specialists. One of the 3 (Case 1) had two biopsies and nine roentgen treatments elsewhere without apparent improvement and 1 patient had been under our own observation for a period of four years for

TABLE 1—SUMMARY OF CASES*

Case	Age, Yrs., and Sex	Complaint	Duration of Symptoms	Smoker	Previous Treatment	Biopsy Report	Pathology Report of Entire Epiglottis	Date of Operation	Further Notes
1	60 M	Hoarseness; dyspnea; dysphagia	1 year	++++	2 laryngoscope biopsies; 9 x-ray treatments	Early carcinoma arising in papilloma	Epidermoid carcinoma, Grade I, arising in papilloma	10-9-45	Patient obese, wt. 280 lbs.; diabetes mel.; arthritis; arteriosclerosis; B P. 160/85; laryngeal obst. requiring tracheotomy
2	52 M	Hoarseness; pain; weight loss	8 months	+++	6300 roentgen units (measured in air)	Epidermoid carcinoma, Grade II	Epidermoid carcinoma, Grade II	11-1-46	First seen 8/19/43; biopsy Grade II carcinoma; treatment 6300 r units; lesion disappeared; recurred 4 years later on epiglottis; B P. 130/70.
3	63 M	Pain in throat	1 month	++++	None	Epidermoid carcinoma, Grade II	Epidermoid carcinoma, Grade II	2-6-47	Arteriosclerosis of legs and aorta; blood pres. 130/70
4	49 M	Hoarseness	3 months	+++	Local to throat	Epidermoid carcinoma, Grade II	Epidermoid carcinoma, Grade III	1-27-48	Good general condition
5	65 M	Pain; dysphagia; irritation	3 years	++++	4 months local treatment to throat	Carcinoma too necrotic to classify	Epidermoid carcinoma, Grade III	9-30-48	Mass in chest secondary to stab wound in his early 20's; B P. 166/80. Right block dissection of neck for metastases

* In all cases serological findings were negative and cervical nodes were not involved.

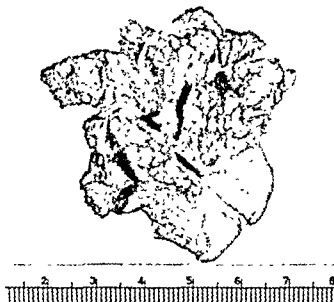


Fig 241 — Epiglottis removed in Case 1. Photograph taken three years after operation after fixation in formalin



Fig 242 — Epiglottis removed in Case 3, fresh specimen

a known carcinoma of the larynx which had been treated with roentgen rays. The entire lesion had disappeared. An area recurred on the epiglottis for which biopsies were taken on two occasions and a diagnosis

of papilloma made. Four years after treatment the area took on a change with some induration, and biopsy at this time revealed early epidermoid carcinoma, Grade II, arising in papilloma. The epiglottis was then removed.

One patient was in quite good general physical condition; a second was in quite good condition other than considerable arteriosclerosis with calcification of the arteries of his legs and of the aorta. One had a thrombophlebitis of the right leg; another a mass in the chest, probably associated with an old injury, as a result of a stabbing in his twenties. His blood pressure was 166 mm. of mercury systolic and 80 mm. diastolic. One patient was in poor general condition with diabetes, obesity, arthri-



Fig 243.—Epiglottis removed in Case 5, fresh specimen

tis and mild hypertension. This patient (Case 1) was so dyspneic from the obstruction that a tracheotomy was necessary before further work could be done.

A biopsy was carried out on all patients before the epiglottis was removed. The biopsy in one patient revealed early carcinoma arising in the papilloma. A second showed carcinoma too necrotic for classification. The other 3 revealed epidermoid carcinoma Grade II on biopsy.

After removal of the epiglottis, the margins of the specimens were studied for completeness of removal. The early carcinoma arising in the papilloma proved to be early epidermoid carcinoma, Grade I. The carcinoma too necrotic for classification proved to be Grade III. One carcinoma which was Grade II on the biopsy was revealed by the entire

specimen to be Grade III. The remaining two were Grade II on examination of the entire specimen as well as on the biopsy.

None of these patients showed cervical metastases at the time of operation and so far only one of them (Case 5) has shown cervical metastases. A complete dissection of the right side of the neck has been done. These patients must be carefully followed and, should metastases occur, a dissection of the neck should be carried out.

In Case 4 there was a question of adequate margin and this patient was given a full course of roentgen treatment after removal of the epiglottis.

COMMENT

Five cases in which the technic described was employed are cited as evidence that the entire epiglottis can be removed without seriously interfering with the function of the larynx. The first case, an elderly obese farmer with arteriosclerosis, diabetes and marked laryngeal obstruction, demonstrates that use of this procedure can be extended to include even a poor risk patient. It has been my experience with carcinoma of the epiglottis that metastases have occurred in the neck and have not occurred in the larynx itself, the larynx being involved only by direct extension from the epiglottis. Therefore, it seems hardly necessary to remove the larynx unless the lesion has extended into it as well as on the epiglottis. It is true that when the lesion is in the midline, one does not know to which side metastases will occur, and they may occur on both sides. It is probable, however, that carcinoma will metastasize more often to the side on which the epiglottis is most involved. Therefore, when no evidence of metastases can be found it is justifiable to remove the epiglottis and keep a careful follow-up on the patient for evidence of metastases into the neck. Should metastasis occur, dissection of the neck is in order. In Cases 4 and 5 had the original biopsy been recorded as Grade III (and a very generous specimen was obtained), much more radical operative procedures could justifiably have been carried out, that is, the bilateral complete block dissection of the neck. On the side most involved, this should include all structures from the skin to the vertebral fascia from the clavicle to the base of the skull and floor of the mouth, from the trapezius across the midline of the neck, sparing the vagus and hypoglossal nerves, the common and internal carotid arteries and the brachial plexus. On the less involved side the jugular vein may also be spared. The larynx is removed with the body of the hyoid bone, the pre-epiglottic space and the ribbon muscles of the neck, leaving the thyroid gland.

Such complete surgical dissections are necessary in advanced laryngeal carcinoma and in carcinoma of the higher degrees of malignancy. The

criticism that the treatment in Cases 4 and 5 was too conservative is justifiable. Complete dissection was performed at the first evidence of metastasis in Case 5.

SUMMARY AND CONCLUSIONS

A method is described for removing the epiglottis by combined laryngofissure and subhyoid pharyngotomy, which is suitable for carcinoma limited to the epiglottis and without evidence of metastasis.

Five reported cases demonstrate that the complete removal of the epiglottis does not seriously interfere with the function of the larynx.

For carcinoma of the higher grades of malignancy involving both the epiglottis and the larynx, or any advanced carcinoma of the larynx with metastasis, surgical removal must include block dissection of the neck and the larynx.

An opinion is expressed concerning the value of radiation therapy and the value of surgery in cases of carcinoma of the larynx.

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THE TECHNICAL ASPECTS OF ESOPHAGEAL SURGERY

HERBERT D. ADAMS

In a symposium on operative technic¹ in 1942, I reviewed some of the technical aspects of esophageal surgery. At that stage of its development, lacking the protection afforded by penicillin and streptomycin, with the exception of the cardia and lower end of the esophagus, we were struggling with cumbersome, multistaged and highly unsatisfactory antethoracic esophagoplasties. In marked contrast, today we can resect the esophagus at any level and reestablish the continuity of the gastrointestinal tract. The technical aspects and safety factors in these procedures are now so well established that it is feasible to do even palliative resections with as much facility as at other levels in the gastrointestinal tract. In addition, considerably greater varieties of lesions of the esophagus are now being treated surgically, with constantly improving operative technic.

Since most of the important surgical diseases of the esophagus are obstructing in nature to some extent, there are common symptoms of varying degrees and combinations of dysphagia, regurgitation and substernal pain and distress. These symptoms are of great significance since they are frequently caused by such important clinical diseases as diverticulum, cardiospasm, esophagitis, stricture, benign tumors and carcinoma. Such patients, therefore, deserve careful roentgenologic studies and esophagoscopy, if indicated, since an early diagnosis and early treatment are essential for good results. The diagnosis having been established, most of these lesions are now amenable to surgery, with uniformly good results. Some of the more important technical aspects in the management of these obstructing esophageal lesions are, therefore, presented.

DIVERTICULA OF THE ESOPHAGUS

Diverticula of the esophagus are common and are classified into the traction and pulsion types. The traction type of diverticula is usually found in the midthoracic esophagus in relation to the hilar structures and rarely reaches a size significant to cause obstructive symptoms. However, the inflammatory process, usually arising in hilar nodes, which during the healing and retraction stage produces the outpocketing and diverticulum, occasionally involves the entire wall of the esophagus with a resultant progressive obstruction owing to stricturing of the esophagus rather than to the effect of the diverticulum. In this case, a high transpleural resection of the esophagus is necessary, with an esoph-

agogastric anastomosis above the arch of the aorta. The technical aspects of this procedure will be discussed more fully with reference to carcinoma at the various levels.

The pulsion type of diverticulum is common, particularly in the cricopharyngeal region and in the lower third of the thoracic esophagus, and usually reaches a size sufficient to produce obstructive symptoms. In this type of diverticulum, the dependent sac reaches such a size that, when filled with food, the weight is sufficient to angulate the esophagus at the neck of the diverticulum so that the lumen of the esophagus immediately below this point is completely obstructed. Because of the great

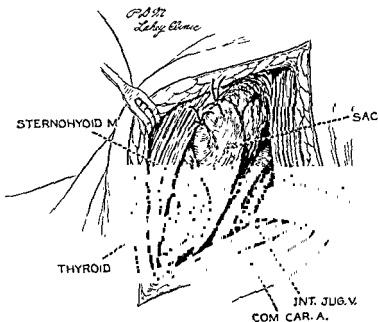


Fig. 244—First stage dissection of pulsion diverticulum of the cervical esophagus. Sac is elevated and sutured to the edge of the sternohyoid muscle.

hazard of mediastinitis before the advent of penicillin, the esophagopharyngeal pulsion diverticula were best operated on by a two-stage procedure. At the first stage the sac was freed, elevated and usually sutured to the sternohyoid muscle, which overcame the esophageal obstruction, allowed free drainage from the sac and sealed off the fascial planes leading from the cervical region into the mediastinum (Fig. 244). At the second stage, about a week after the primary stage, the actual resection of the sac was carried out. Also before penicillin came into use, 3 patients with large pulsion diverticula of the lower thoracic esophagus were operated upon but at this level the sac was carefully freed up and the apex of it sutured as high as possible, suspending it to the

mediastinal pleura. This diverticulopexy without subsequent resection (Fig. 245, *a* and *b*) gave very satisfactory results without the danger of mediastinal or pleural contamination. Since antibiotics became available, these large diverticula of the lower third of the esophagus have been resected in one stage. The diverticulum is carefully mobilized, preserving the muscularis fibers encircling the neck of the diverticulum.

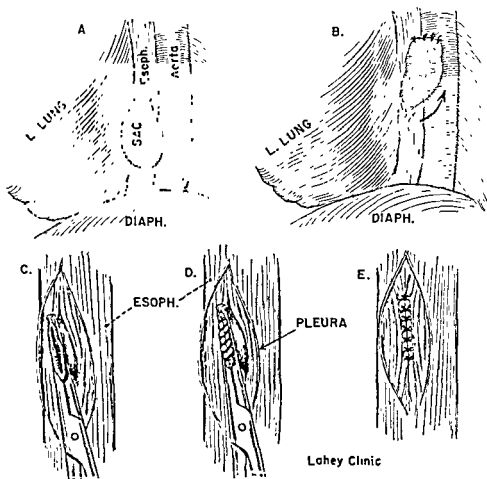


Fig. 245—*a* and *b*, Diverticulopexy of large pulsion diverticulum of the lower thoracic esophagus.

c, *d* and *e*, One stage resection of pulsion diverticulum of the thoracic esophagus (Reprinted from *J. Thoracic Surg.* 17: 642 [Oct] 1948.)

The most important technical detail of all is to avoid too much traction on the sac at the time the clamp is placed across the neck in order not to remove too much mucosa opposite the neck of the diverticulum, thereby narrowing the lumen of the esophagus and stricturing it at this point. A thin clamp is placed across the neck, the sac removed beyond the clamp (Fig. 245, *c*, *d* and *e*). The clamped edge is then whipped over with a continuous chromic suture and a relatively aseptic closure

made in this manner. The carefully preserved muscularis layer dissected from the neck of the sac is then closed with interrupted silk sutures.

It is also important to be aware of the fact that in at least half of these cases of large obstructing pulsion diverticula involving the lower third of the esophagus there is an associated intractable cardiospasm with advanced cicatricial stricturing of the cardia as well. If this is not recognized and the diverticulum alone treated, the obstruction, of course, will not be relieved and it will become necessary to reoperate on this patient and resect the cardia. In patients who have both a large pulsion diverticulum and cardiac stricture, it is best to resect the cardia and the esophagus to above the neck of the diverticulum and then do an esophagogastric anastomosis at that level. The technical aspects of resection of the lower esophagus will be discussed later in this paper.

CARDIOSPASM

Cardiospasm alone is a common obstructing lesion of the esophagus, and is seen with all degrees of cardiac structural changes and esophageal dilatation. It is true that a large proportion of these cases, and particularly those without extensive cicatricial stricturing of the cardia and marked dilatation of the esophagus, can be managed by dilatations. However, if for a variety of reasons dilatations are unsatisfactory, these patients should be submitted to surgery. If one is dealing primarily with cardiospasm without much associated cicatricial stricturing of the cardia, then a *cardioplasty* will give good results. An incision is made in the long axis of the lower end of the esophagus on the fundal side, carrying it through the cardia and out onto the fundus itself. This incision is then closed transversely, thereby satisfactorily enlarging the cardiac aperture (Fig. 246). In the patients in whom there has been marked replacement of the cardia with dense scar tissue and a true stricture has formed, and in those patients in whom there is marked mega-esophagus, however, this is not a satisfactory procedure and the lower end of the esophagus and the cardia must be resected and an esophagogastric anastomosis made. In some of the cases of extreme mega-esophagus filling the greater part of the chest the greater part of this sacculated esophagus must be resected and a high esophagogastric anastomosis made. Some of these patients will require a simple gastrostomy in order to improve their nutritional condition and to clear up the inflammatory process and infection within these huge sacculated dilatations before resection.

STRICTURES OF THE ESOPHAGUS

Patients with advanced strictures of the esophagus, whether due to the ingestion of caustics or to esophagitis from infection and ulceration,

or the esophagitis associated with the ulcer diathesis and duodenal ulcer, must likewise be treated by adequate resections. The extent of such resections would depend entirely on the level to which the esophagus is involved and the technical aspects at these various levels will be described later.

TUMORS OF THE ESOPHAGUS

Finally, the most common obstructing lesion of the esophagus is tumor. Such tumor involvement may be an extension and secondary to involvement of the esophagus from some other organ in close relationship to it, such as the bronchus, or it may be primary in the esophagus itself. The commonest form of primary tumor of the esophagus is carcinoma, although occasionally a benign tumor is seen. Because of their

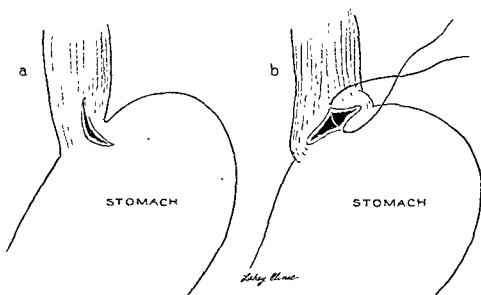


Fig. 246—*a* and *b*, Cardioplasty for cardiospasm without cicatricial stricture

rarity and their amenability to cure, benign tumors are of considerable interest. They consist of esophogenic cysts, polyps, fibromas and leiomyomas. They are of technical interest since they rarely require an esophageal resection. The esophagus at the level of the tumor is carefully mobilized so that the dissection of the tumor can be carried out under direct vision (Fig., 247). The fibromas and leiomyomas are intramural and encapsulated and can be carefully dissected out of the muscular wall of the esophagus without extensive damage to the muscularis and usually without opening the mucosal layer. The muscularis is then carefully reconstructed with fine interrupted silk sutures. If the tumor is pedunculated or mainly intraluminal, the base can be excised, thereby opening the mucosa. All layers must be carefully reapproximated with fine interrupted silk sutures.

Esophageal Resection.—Carcinoma of the esophagus is very common and if the diagnosis is made at an operable stage it can be safely resected at any level, including the superior thoracic strait, and the continuity of the intestinal tract reestablished by displacing the stomach through the diaphragm into the thorax for an esophagogastric anastomosis. All patients in whom esophageal resection is contemplated for any of the

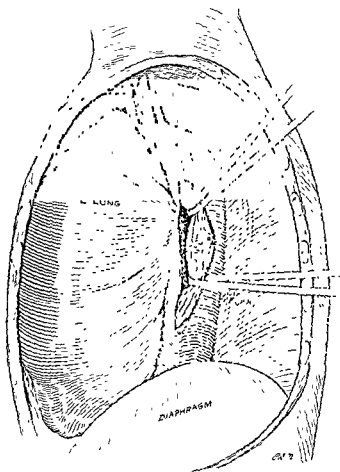


Fig 247 —Surgical exposure and mobilization of the esophagus for excision of a benign tumor.

variety of lesions described must be carefully prepared before operation, particularly if they have lost considerable weight and are in a poor state of nutrition. They should be given multiple transfusions and intravenous glucose and amino acids to supplement whatever nourishment they are able to take by mouth. The inflammatory reaction which is usually associated with these lesions should be treated during this time by administration of 300,000 units of crysticillin (penicillin plus procaine) twice

daily. It is also preferable to have these patients come to the operating room with a Levin tube down to the point of obstruction.

These patients are operated on in the lateral position under endotracheal oxygen-ether anesthesia.

Lesions in the Cervical Esophagus or the Superior Thoracic Strait.—A low cervical incision is made to determine operability and to free up this portion of the esophagus down into the superior mediastinum. If the lesion has not extended to the carotid sheath and cervical nodes, or the mediastinal structures, or the membranous portion of the trachea and can be freed up satisfactorily, the thorax is then opened by a posterolateral incision, resecting the sixth rib and cutting the fifth and seventh ribs behind the angles, close to the transverse process. The mediastinum is then opened above the arch of the aorta and the esophagus at this level mobilized and carried up to the level of the dissection from the cervical incision. With the lesion mobilized from above and below, the remainder of the esophagus is freed up from the mediastinum, the diaphragm opened widely, the gastrosplenic and gastrocolic mesenteries are then opened into the lesser omental space, the short gastric arteries are divided and the greater curvature of the stomach mobilized well down toward the antrum and pylorus. The cardiac attachments below the diaphragm are mobilized and the gastrohepatic mesentery, including the left gastric artery, are then secured and divided down to the pyloric region. The esophagus is divided immediately above the cardia and the cardia closed. The inner end of the left clavicle and first rib are then resected and the fully mobilized stomach passed transthoracically into the neck for an anastomosis between the cervical esophagus and the top of the fundus of the stomach. The detail of such anastomosis is the same at any level, that is, a two-layer anastomosis entirely of interrupted sutures. The esophagus is transected below the lesion, never above the lesion, because of the marked retractability of the esophagus, until the posterior row of sutures is made between the esophagus above the lesion and the top of the fundus. An opening at the appropriate point is made in the stomach and the posterior wall of the esophagus. The second row of interrupted fine silk sutures is placed including all layers of the esophageal wall, with careful apposition of the esophageal and gastric mucosa. The esophagus is completely transected at this level and the interrupted layer continued around to the anterior portion of the anastomosis and finally the first musculoserosal layer is likewise completed anteriorly. The cervical, mediastinal and thoracic areas are then sprayed with penicillin solution and the wounds carefully closed, leaving a small Penrose drain in the cervical wound and an intercostal catheter within the chest for suction drainage.

Lesions in the Upper Thoracic Portion of the Esophagus.—For lesions

in this position in relation to the arch of the aorta and the hilar structures of the lung, a similar type of transthoracic approach is carried out, the mediastinal pleura is opened below the arch of the aorta down to the diaphragm, the lower part of the esophagus is mobilized and retracted out of the mediastinum and a careful dissection is carried up toward the hilar structures. By careful manipulation and dissection these structures can be freed from the esophagus under direct vision, avoiding damage to the inferior pulmonary vein or the bronchus. In many instances at this level the mediastinal pleura of the opposite thorax is adherent to the lesion either by direct extension of the carcinoma or by an associated inflammatory process. Even if this pleura has not been involved by these processes, it is still so very thin that it is advisable to dissect it from the esophagus under direct vision in order to avoid opening it. If the pleura of the opposite thorax is opened it will become necessary for the anesthetist to carry on the remainder of the operation with positive pressure which in turn partially reexpands the lung in the left thorax, making it more difficult to obtain a good exposure for the delicate dissection necessary and for the anastomosis high in that thorax. If this pleura is involved, however, it should be excised, after a warning to the anesthetist so that he can apply positive pressure and avoid producing a pneumothorax of any untoward degree on the opposite side. If possible, the mediastinal pleural opening into the other thorax should be closed with fine interrupted silk, although in many instances the pleura is so thin that it is impossible to do so, and the positive pressure must be maintained throughout the procedure.

After the lesion is freed to above the hilar structures, the esophagus must then be carefully freed from behind the arch of the aorta. The mediastinal pleura is opened above the arch and the esophagus freed at this level. The diaphragm is opened and the stomach mobilized as previously described. The esophagus is transected at the cardia and the cardia closed, the lower transected end of the esophagus is tied off with a heavy braided silk and the end covered with the thumb from a rubber glove and tied firmly over the end. The esophagus and the lesion are carefully displaced upward behind the arch of the aorta and pulled out from above the arch and traction is maintained on the esophagus until the posterior rows of the anastomosis are completed as described, the anastomosis being made above and anterior to the level of the arch of the aorta (Fig. 248).

It is important to realize that in these higher resections there is a marked physiologic disturbance which is of great significance in the postoperative management in these cases. There is almost total displacement of the stomach into the thorax, the stomach itself is extensively denervated by a high vagotomy, there is a marked reduction and

disturbance of the blood supply, and it is therefore prone to dilatation as it lies across the pericardium. If such a dilatation in this particular position is allowed to take place, there will be severe cardiorespiratory disturbance which may be so profound as to cause the death of the patient. Therefore, at this level a Levin tube, which is placed down to the obstructing lesion before operation, is passed through the anasto-

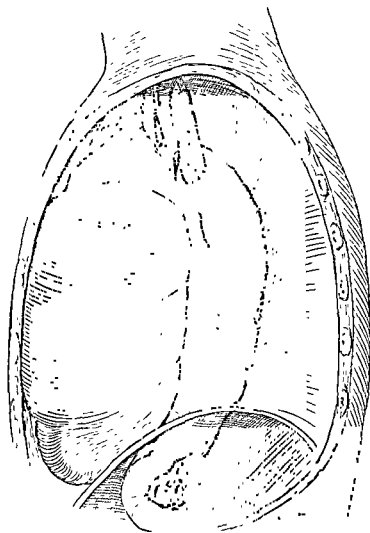


Fig. 248.—High esophageal resection with esophagogastric anastomosis superior and anterior to the arch of the aorta.

mosis at the time of completing the anterior rows of the anastomosis to the level of about the mid stomach opposite the pericardium. This tube is kept on suction for three to four days following operation and the stomach not allowed to dilate at any time. Contrary to past teachings we have not seen any complications arise from such a tube lying across the line of anastomosis, producing or contributing to a breakdown of the

anastomosis. These patients must be carefully watched, and all signs of disturbed cardiac or pulmonary dynamics should be corrected. All patients subjected to esophageal resection receive large doses of penicillin, 100,000 units every three hours during the immediate postoperative stage and then the crysticillin, 300,000 units twice a day if no signs of infection develop. Those patients in whom the opposite mediastinal pleura has been opened must be watched with particular care, being certain at the close of the operation that the lung on the opposite side is fully expanded. A thoracentesis should be done if the lung does not seem to be properly expanded. This side, of course, must be watched for further signs of pneumothorax or effusion, since these patients will not stand even moderate degrees of increased pleural pressure in either thorax.

Lesions of the Lower Third of Esophagus and Cardia.—Patients with carcinoma or lesions of the lower third of the esophagus and cardia are likewise prepared in a similar manner and operated upon through a posterolateral incision, usually removing the seventh or eighth rib and cutting the rib immediately below, behind the angle. The lower esophagus is mobilized, the diaphragm opened and the upper part of the stomach mobilized as already described and, since in most instances it is necessary to excise part of the stomach, including the cardia, the resulting opening in the transected stomach is usually considerably larger than the esophagus above the lesion. The accepted method is to close this opening and to make another opening in the stomach as is done in the higher resections. It has been my experience, however, that the cardiac lesions frequently require resection of a considerable portion of the stomach and to a greater extent along the lesser curvature side. Under these conditions I have repeatedly closed this long oblique opening in the stomach, leaving only an adequate aperture on the greater curvature side at the end of this closure for the anastomosis with the esophagus (Figs. 249, 250 and 251). In spite of the past teachings that an anastomosis in a suture line is undesirable, this has worked out very satisfactorily without complications. It also has the advantage of very readily adjusting the gastric opening to the size of the esophagus above. In these lower lesions, however, the esophagus is very commonly not dilated at all and is frequently even contracted to a smaller caliber than normal, and it is in this type of anastomosis that one is likely to get a postoperative stricture and poor function. Under these conditions it is best to increase the size of the anastomosis by enlarging the end of the esophagus by cutting the lateral wall upward for a short distance (Fig. 252). This is superior to an oblique incision across the esophagus since the circulation in the tip of an obliquely transected esophagus is poor.

In all cases of esophagogastric anastomosis in which the stomach is

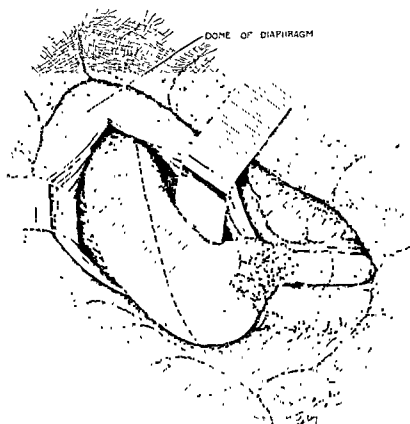


Fig 249.—Exposure and mobilization of the cardia and lower esophagus. Dotted line shows line of resection.

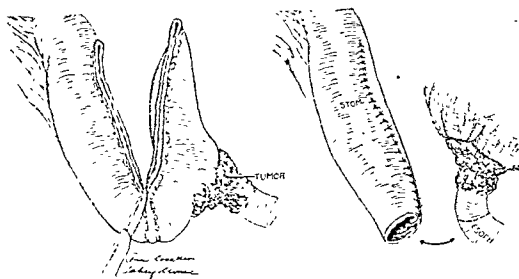


Fig 250.—Technic of transection of the stomach, closure and formation of the gastric stoma.

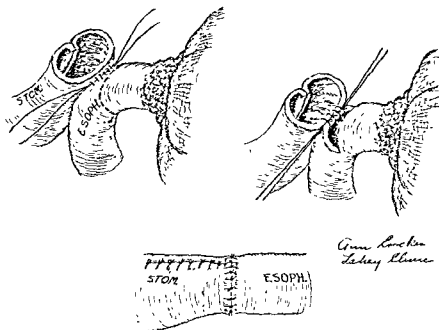


Fig. 251 —Technic of the esophagogastric anastomosis

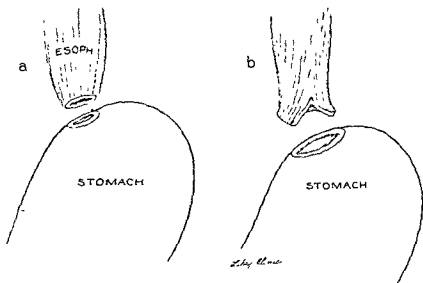


Fig. 252 —Method of enlarging the esophageal lumen to increase the size of the esophagogastric stoma

displaced into the thorax, the diaphragm must be permanently paralyzed by resecting a length of the phrenic nerve as it crosses the pericardium. The diaphragm is then closed, leaving a very adequate opening for the stomach at whatever level it passes through this structure. In all instances an intercostal catheter is left within the chest for suction to aid in rapid reexpansion of the lung. We have not found it necessary to leave a Levin tube in the stomach in the lower esophageal resections.

There are, of course, many fine details in technic that could not be included in a discussion of this length but the major details in esophageal surgery have been presented. By their careful application, esophageal surgery is safe and excellent results can be obtained.

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THE GENERAL TECHNICAL ASPECTS OF CARDIOVASCULAR SURGERY

HERBERT D. ADAMS

Cardiovascular surgery received a tremendous impetus during the recent war years. Knowledge gained by experience with serious traumatic cardiovascular lesions familiarized us with the problems and technical aspects of this field of surgery. In addition, during these same years came the outstanding contributions of Taussig, Blalock, Gross, Crafoord and others in the surgical treatment of congenital cardiovascular lesions. Since that time the technical aspects of cardiovascular surgery have become more standardized, with constantly improving results and widening scope. Even intracardiac lesions are now beginning to be attacked surgically, and this whole field of surgery is changing rapidly. Some of the general technical aspects of the more common cardiovascular operations are, therefore, presented.

A brief reference to *arterial aneurysm* and *arteriovenous aneurysm* should be included in any discussion of cardiovascular surgery. In certain selected cases an arterial aneurysm can be mobilized and wrapped with polyethane. In others, the vessel can be ligated and the aneurysm excised or, more recently, excision of the aneurysm with free arterial graft may be possible.

Arteriovenous aneurysms, either traumatic or congenital, in most instances are best handled by quadruple ligation and excision (Fig. 253). In some locations such as the carotid, popliteal artery or aorta, aneurysmorrhaphy or, better, excision and free arterial graft, is preferable because of the serious circulatory complications that arise following ligation of these particular vessels.

Of even greater interest at the present time are the operations for congenital cardiovascular lesions, including patent ductus arteriosus, coarctation of the aorta and pulmonary stenosis. The earliest surgical attempts at obliterating a *patent ductus arteriosus* were done by exposure of the ductus and simple ligation.⁴⁴ This method did not prove to be entirely satisfactory since there were recurrences following this simple ligation and, therefore, two other more satisfactory methods have been devised. Gross has developed and perfected the technic for complete division of the ductus and we have used this procedure very satisfactorily in children. This consists of an anterior approach (Fig. 254). The mediastinum is opened and the patent ductus localized by palpation for the thrill and by its relationship to the vagus and recurrent laryngeal nerves (Fig. 255). It is then very carefully mobilized, particularly in freeing it

up posteriorly. The ductus is also carefully mobilized in its full extent well back onto the pulmonary artery and the aorta, and all extensions of the pericardial sac are freed from it. Four thin clamps are then applied to the ductus and the ductus cut across between the two central

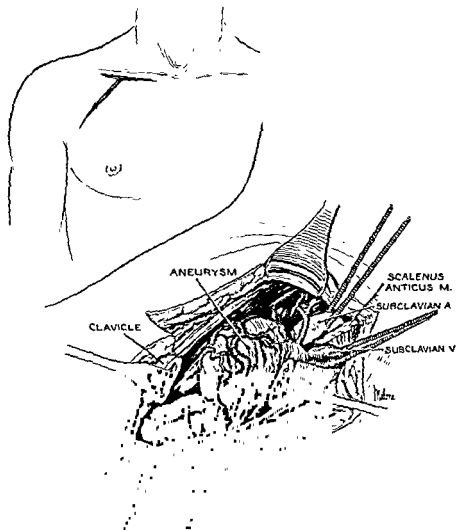


Fig. 253.—Arteriovenous aneurysm involving the subclavian vessels. The surgical approach for quadruple ligation and excision is shown (Published with permission of C. V. Mosby Co., St. Louis; from "Arterial Injuries of the Thorax" by Dr. Herbert D. Adams, *J. Thoracic Surg.*, October, 1919, p. 642.)

clamps (Fig. 256). In succession, the two distal clamps are removed so that the protruding cuff may be closed with continuous sutures (Figs. 257 and 258). This procedure does have the disadvantage of the possibility of one of the remaining clamps slipping off during closure either

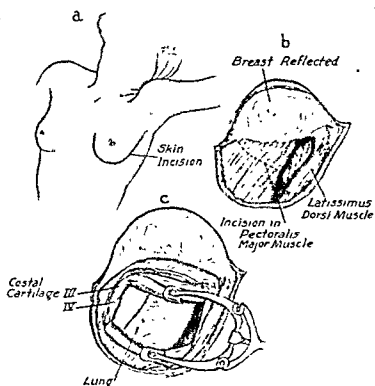


Fig. 234.—Anterior approach for exposure of patent ductus arteriosus.

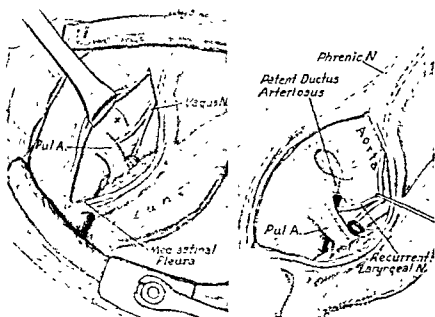


Fig. 233.—The mediastinal exposure of the patent ductus arteriosus and its relationship to the recurrent laryngeal nerve.

because of application of a poor clamp or because of friability of the wall of the ductus, and we have not felt that it was safely applicable to adults.

We have, therefore, adopted the method of ligation suggested by Blalock (Fig. 259, c) by ligating the ductus as close as possible to the

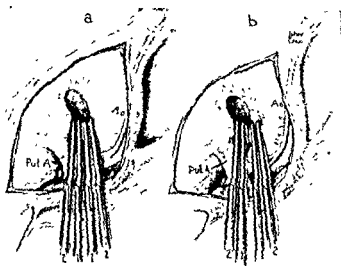


Fig. 256 —The application of four clamps to the ductus and division between the two central clamps

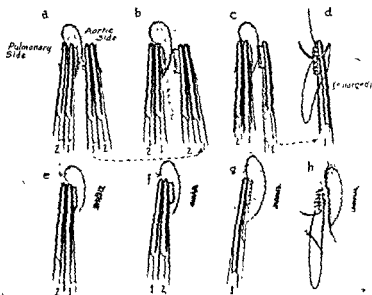


Fig 257 —Detail of suture of the cut ends of the ductus by successively removing the two distal clamps and suturing the protruding cuff beyond the two proximal clamps

aortal and pulmonary ends and using a transfixion suture ligature between these two ligatures. In some instances in which it has been

impossible technically to place the transfixion stitch because of the shortness and large diameter of this ductus, these ligatures have been wrapped with umbilical tape or polyethane. Recently we have considered using a reverse Potts' technic, employing a posterolateral approach, mobilizing the aorta and the ductus, and applying a Potts clamp across the aortal end of the ductus (Fig. 259, *a* and *b*) and a small clamp on the pulmonary side. The ductus is then divided leaving sufficient stump at either end for easy and safe closure.

In a similar way, in our surgical management of *coarctation of the aorta* we have had to alter to some extent the technical aspects of these operations as we have applied these procedures to the higher age groups. In these cases, particularly in patients over 30 years of age, the aorta is thinned out, friable and contains considerable arteriosclerotic changes

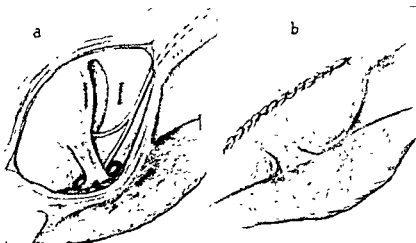


Fig 258.—The proximal clamps have been removed and the mediastinal pleura closed

and plaques and therefore we have not thought that it was advisable to depend for our anastomosis on simple running, everting sutures. Using a posterolateral approach, in the coarctations of greater length, around $1\frac{1}{2}$ inches, we have done a resection and have mobilized the greatly enlarged subclavian artery and swung it down to do an end-to-end anastomosis with the aorta. This anastomosis is made using interrupted everting sutures around the entire periphery of the anastomosis and then reinforcing this with a running stitch, whipping over the everted edges, each stitch going half way around the circumference (Fig. 260). In coarctations of shorter length we have resected this coarctated area and done a primary anastomosis of the aorta, using the same technic (Fig. 261).

In *pulmonary stenosis in the tetralogy of Fallot* we have again been dealing with the older age groups and have found the vessels more

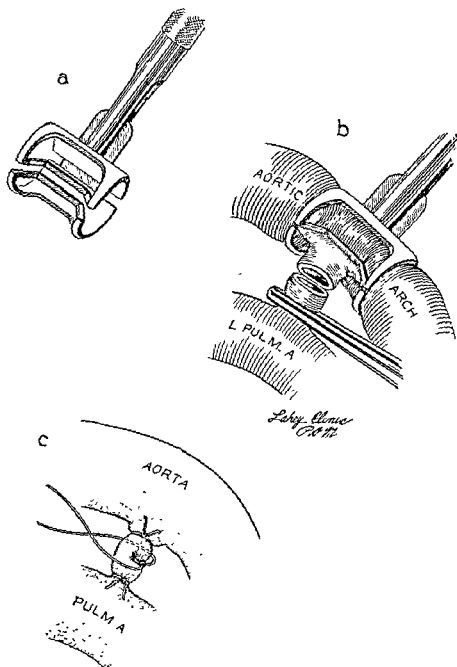


Fig 259 —a, Potts' clamp b, Application of Potts' clamp to aortic end of the patent ductus arteriosus. A hemostat is applied to the pulmonary end and the ductus divided for suture closure c, Ligation of aortic and pulmonary ends of the ductus with a transfixion ligature between

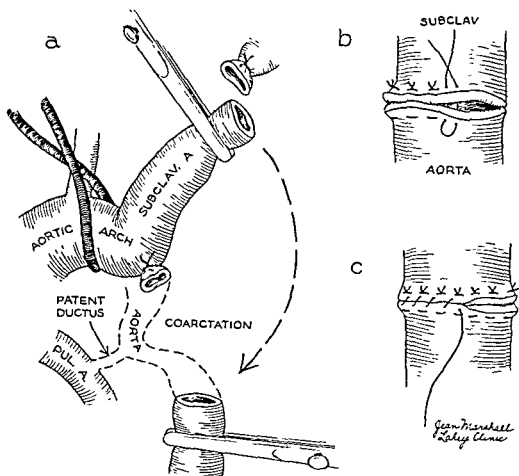


Fig 260 —a, Resection of coarctation and mobilization of subclavian artery for end-to-end anastomosis with descending thoracic aorta.

b, Detail of end-to-end anastomosis, everting interrupted sutures around entire circumference

c, Everted edges reinforced with continuous sutures, each covering half the circumference. (Published with permission of the Journal of the American Medical Association; from "Coarctation of the Aorta", by Drs. Herbert D Adams, David I Rutledge and Carlton R Souders, J. A. M. A., February 5, 1949)

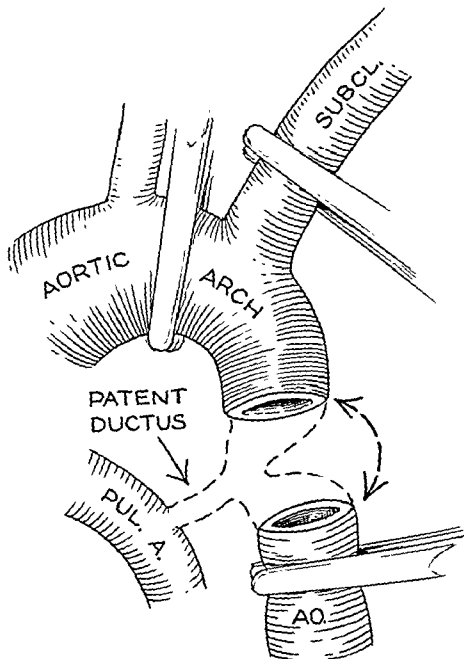


Fig 261 —Resection of the coarctation and primary end-to-end anastomosis of the aorta. Detail of anastomosis as in Figure 260, b and c (Published with the permission of the Journal of the American Medical Association, from "Coarctation of the Aorta," by Drs Herbert D Adams, David I Rutledge and Carlton R Souders, J A M A, February 5, 1949)

difficult to handle because of their greater friability and decreased elasticity. However, we have employed the Blalock technic, utilizing either the right or left subclavian artery for anastomosis with the corresponding pulmonary artery (Fig. 262). Using an anterior approach, the mediastinum is opened and the subclavian and pulmonary arteries are mobilized and in most instances the end of the subclavian is anastomosed to the side of the pulmonary artery, using a single row of simple over-and-over sutures, each continuous suture covering half of the circumference of the anastomosis (Fig. 263). We have not used the Potts technic, producing an aortal-pulmonary fistula by use of his ingenious clamp, but there are probably instances in which this technic would be the one

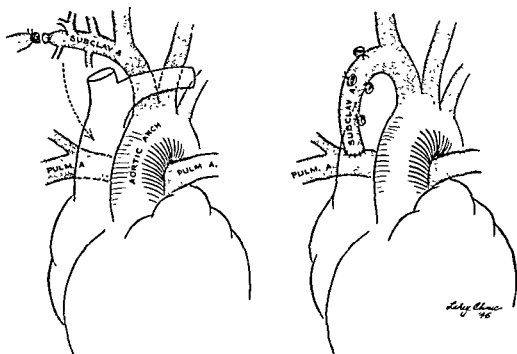


Fig 262 —Pulmonary stenosis. Right subclavian-pulmonary artery shunt.

of choice and we have been prepared to use this method if it was impossible to use the Blalock procedure for any reason.

For completeness, it is well to mention the fact that various surgical procedures are now under development for the surgical management of mitral stenosis. These consist primarily of valvotomies and shunt operations such as the production of an artificial atrial septal opening, or a shunt between the systemic veins and the pulmonary veins.

Intracardiac surgery, however, is still done blindly and is, therefore, greatly limited, and it will remain for the development of an artificial method of by-passing the heart so that intracardiac surgery may be done under direct vision and with highly accurate technic.

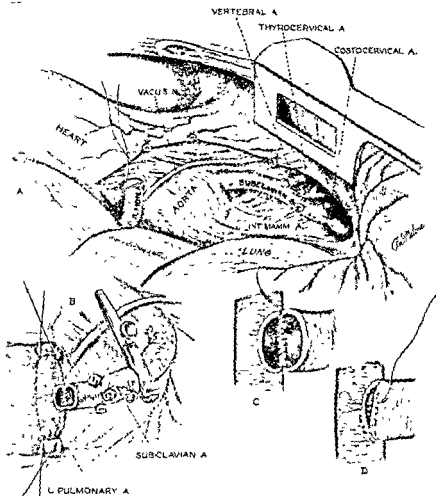


Fig 263 — Pulmonary stenosis Left subclavian-pulmonary artery shunt a, Exposure of subclavian and pulmonary arteries b, Detail of control of the vessels during the anastomosis c and d, Detail of sutures used in anastomosis

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THE TECHNIC OF TOTAL PNEUMONECTOMY

DAVID P. BOYD

GREAT strides have been taken in pulmonary surgery since the early successes of Graham, Rienhoff and Crafoord and their early descriptions of the technic of pneumonectomy. The studies of Churchill, Blades and others have opened new chapters in surgical anatomy and extended the technic of resection of the lung to include lobes and segments with increasing precision.

No attempt will be made to discuss the specific problems which various lesions present. Rather a broad approach will be taken to the problems of lung resection as a whole. Whether for cancer, abscess, bronchiectasis or even tuberculosis, the technical problems are essentially the same. Indeed, frequently more than one of these lesions are present in the same lung.

ANESTHESIA

In the thoracic team the anesthetist holds an important place. Without him, these operations are more difficult and dangerous. It is rare that pneumonectomy is an elective operation which can be postponed indefinitely or one in which the condition of the patient can be greatly improved. Many patients requiring this procedure have coronary sclerosis and emphysema. In addition to this, many have a low vital capacity and diminished cardiorespiratory reserve. Furthermore, many of these patients who are considered for total pneumonectomy because of low grade epidermoid carcinomas of the bronchus have not lost weight and often have an undesirable degree of obesity. The presence of large amounts of mediastinal and pericardial fat is just as disturbing to the thoracic surgeon as is extensive fat infiltration of the mesentery and abdominal viscera to the abdominal surgeon. When all of these things are considered it is obvious that the requirements for successful anesthesia in many of these cases are of the utmost importance. It is particularly important to avoid anoxemia in these operations. It is for this reason that we are reluctant to use pentothal sodium at any time during these operations. No one can foretell when pentothal sodium is used which patient will have laryngospasm and which will not. Laryngospasm brings about anoxemia and even if it is temporary, this anoxemia may be sufficient to cause irreparable damage in a patient with a low respiratory reserve.

Perhaps the next consideration of importance is the maintenance of an airway free from secretions. This is of the greatest importance in patients

other possible advantage is that the operator can sit down from time to time. I have used this incision on numerous occasions with great satisfaction. The only serious disadvantage which I have noted is that it may be extremely difficult to deal with the superior pulmonary vein. The latter is anterior in the hilum and it is necessary to lift the lung up against gravity to secure it. If dissection in this area is particularly difficult, as it occasionally is, this approach makes it more so. All things considered, I believe that this is often the position of choice for pneumonectomy for lung abscess or for tuberculosis.

MOBILIZATION OF THE LUNG

No matter what the indication for pneumonectomy, the lung may be solidly bound to the parietal pleura. In lung abscess, it always is; in bronchiectasis and carcinoma, it frequently is. It is essential to proceed until operability is determined. The synechia between the visceral and parietal pleura may be fibrous, thin and avascular or it may be extremely dense and vascular. The diaphragm and pericardium are frequently involved in this fixation, as are the great vessels in the superior mediastinum. With experience, one soon learns that in these vascular adhesions, careful, slow, tedious, mostly sharp, dissection is required. No finger or gauze dissection should be employed if excessive blood loss and shock are to be avoided. Dissection as far away from the parietal pleura as possible will give the best results. Small tears in the lungs may be easily repaired with hemostatic sutures but bleeding points which are retracted into the thoracic wall are extremely difficult to secure. As soon as the chest wall is opened one can estimate the situation so as to inform the anesthetist that there may be excessive blood loss. Thus, he will be prepared to administer supportive therapy.

THE LARGE SOLID LUNG

Of the numerous impediments which may be encountered in attempting to remove the lung, none is more difficult to deal with than a large, solid, uncollapsible organ. It is especially important in such a situation to have sufficiently wide exposure to allow both hands to move freely within the thorax. This may be secured by dividing additional ribs posterior to the angle. In one case, in which the lung weighed 1500 gm., even this would not permit exposure of the hilar structures. The fifth rib had been resected and the sixth and seventh ribs divided at their posterior articulations. To secure the required exposure the sixth and seventh ribs were severed close to the sternum and turned down as a flap. This procedure gave adequate working space. In another case of solid lung in a poor risk patient with low respiratory reserve, manipula-

tion of the organ caused asystole and hypotension. When the dissection was interrupted and the lung lifted away from the heart, pressure was restored and regular rhythm and systole resumed. By a series of intermittent and rapid sessions of this type, the lung was finally removed.

HILAR DISSECTION

It is well to have a definite and regular plan for dealing with the hilar structures, although expediency may dictate variations from time to time. When all adhesions between the hilum, pericardium and parietes have been freed, the mediastinal pleura is opened as high up on the lung side as possible in order to preserve pleural flaps for closure. In most cases in which radical resection is undertaken, and especially on the left side, it is difficult to obtain enough pleura to close the mediastinum.

After the pleura has been incised all the way around the hilum, the decision regarding resectability must be reached. The presence of paratracheal nodes or nodes elsewhere in the mediastinum too inaccessible to reach, may be determined by palpation. The bronchoscopist's remarks will be borne in mind regarding the amount of available main stem bronchus above the visible tumor. While the pulmonary artery is the first logical structure to attack, I have made it a practice first to investigate both the inferior and the superior pulmonary veins to determine whether there is intravenous or perivenous extension of the tumor. If this is not done the surgeon may find that he has cut across tumor tissue in amputating the lung. This venous involvement may extend into the auricle itself. Dissection of the artery frequently is easy, especially in cases of suppurative disease, tuberculosis, or peripheral neoplasm. The superior pulmonary vein lies antero-inferior to the pulmonary artery and the bronchus and bronchial arteries, postero-inferior, and often simple pledget dissection under direct vision will free enough of the main trunk to permit double proximal and single distal ligation. With the lung on the stretch toward the parietes, the first ligature of number 12 silk is placed on the artery as high in the mediastinum as possible. The anesthetist should be advised as this first tie is placed and the effect on the patient noted before the knot is set. No snaps or other traction device should be applied to this ligature. The next tie is placed as far out on the lung as possible, preferably as a transfixion ligature. Simple ligatures tend to slip off and cause troublesome back bleeding. Often in order to have a satisfactory proximal stump these distal ligatures must be applied to the primary divisions of the artery. A third ligature, also a transfixion, is placed close to the first and securely tied. The vessel is then divided. An important point in technic, perhaps more applicable to the smaller vessels and closer quarters encountered in partial lung resections, is that one should always cut a ligated vessel over a right angle clamp with the

jaws partly open. This step may avoid injury to deeper vessels not yet secured. All fascia and lymph nodes should be removed to obtain a clean arterial surface for a safe and sure ligation. This is a fundamental principle in dealing with large blood vessels. This is the ideal and simplest method for dealing with the pulmonary arteries. However, if the artery is unduly short, or if the hilum is foreshortened by local disease, the branches must be used. Obviously, this is less consistent with radical

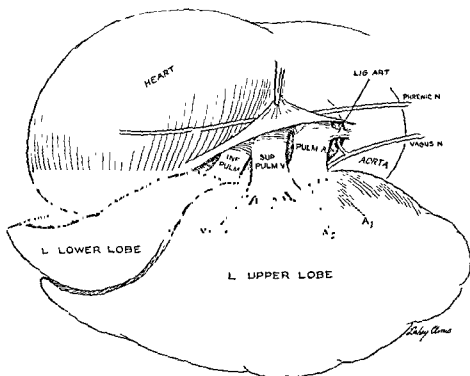


Fig 261—Diagrammatic representation of anterior aspect of hilum. Note main pulmonary artery dividing into apical segmental (A_1), anterior segmental (A_2) and lower lobe vessels. Posterior apical segmental artery (A_3) is obscured by A_1 and A_2 . The artery to the lingula (A_4 and A_5) lies deeper in the fissure. The tributaries of the superior pulmonary vein correspond to the same arteries; the lowermost one shown here is the common vein from the segments of the lingula (V_4 and V_5).

excision but safety may take precedence. Furthermore, in long-standing inflammatory disease, considerable difficulty may be encountered in dissecting the vessels from the upper lobe. Nevertheless, painstaking dissection will always be rewarded by secure ligations even in the presence of the worst adhesions and adenopathy, provided malignant infiltration has not occurred.

Occasionally, the cancer may extend into the hilum between the

branches of the artery. This is the most difficult situation of all and is the only justification for the clamp and cut treatment of a pulmonary artery. After securing all the length available by mobilizing the vena azygos on the right and sectioning the ligamentum arteriosum on the left, three dependable clamps are placed on the pulmonary artery. The center one is removed and placed on the mediastinal side of the proximal clamp. It will then be possible to place a satisfactory ligature on the proximal side of the innermost clamp. The artery is cut across at the distal clamp. A 1 or 2 mm. cuff remains which can be reinforced by a continuous over and over fine arterial silk suture. The distal stump is controlled by a suture ligature. Obviously, this method is dangerous, but as operability is extended, hazards and mortality are increased in proportion.

Attention is now turned to the superior pulmonary vein. In most cases secure ligation of the trunk vessel may be obtained. However, the pericardial reflection often extends out onto the anterior surface of this vein and a dependable ligature cannot be applied without removing these extensions, and thereby opening the pericardium. This large vein, furthermore, is thin and may be densely adherent to the bronchus. It may merge into the inferior pulmonary vein in the diseased hilum and occasionally there may be but one large, common pulmonary vein. It is almost always possible to place a satisfactory ligature on the main trunk after which the branches from the lingula and from the remainder of the upper lobe are ligated and divided over a partially opened right-angle clamp, leaving a proximal stump of good length. In a deep chest, in any position except possibly the dorsal recumbent, this vein lies at the bottom of a deep cavity. With poor exposure and inadequate lighting, the stage is set for tragedy. The lung must be lifted backward and outward. The operator must wait until the lights are so adjusted that visibility is unhampered and deliberate, precise handling is possible. If one of the great veins is inadvertently torn, it can usually be managed if exposure and lighting are adequate. A pledget of oxycel gauze should always be within easy reach of the surgeon. With this he can catch the vessel lightly between finger and thumb. With the situation thus temporarily controlled, the field can be sucked dry, lights adjusted, and if necessary, more ribs cut to allow both hands free motion within the thorax. A plan of attack can then deliberately be formulated. Usually, one of two techniques is possible. With the left index finger under the vein which is slightly on the stretch, the thumb can be slowly removed from its anterior surface. If sufficient extrapericardial length remains, a number 12 silk suture can be placed precisely through the wall of the vein proximal to the perforation and tied by an assistant (Fig. 265). Another suture may be placed to occlude the remainder of the vein. Muscle or oxycel may be incorporated. If this procedure is not possible, the peri-

cardium may be opened and the vein secured where it enters the atrium. This is not difficult if manipulation is unimpeded.

Before the inferior pulmonary vein is dealt with, the bronchus should be secured since the bronchial arteries are still pumping blood into the specimen. These are important vessels, especially in older patients, and are at times a surgical problem. We disagree with statements in the literature that they are not significant considerations in lung resections.

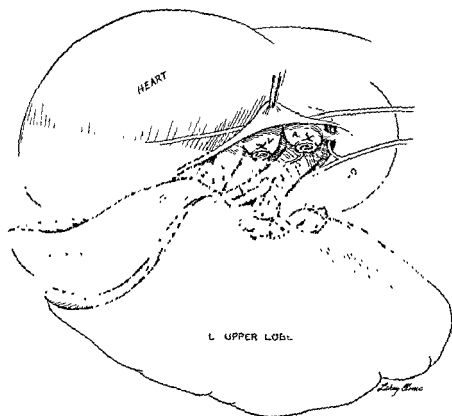


Fig 265 —The artery has been divided as a trunk, followed by division of the superior pulmonary vein, adequate stumps are shown, the ever-present cuff of pericardium on the vein is not shown. The bronchus and its artery are now ready for treatment as indicated in the text and shown in Figure 266.

On the contrary they are constant in their presence, but variable in number, and require precise technique of handling to maintain a dry field during bronchial closure. An attempt is made to isolate these vessels and tie them with fine silk on a French needle about 1 mm. above the proposed line of transection of the bronchus.

Many techniques are advocated for closure of the bronchus, an organ which, as Clagett pointed out, was specifically designed by nature to stay open at all times. Most surgeons believe that their special methods

have given steadily improving results. The avoidance of ulceration and infection of the stump, which we owe to chemotherapy, is probably the important factor. A technic which avoids crushing clamps, necrotizing chemicals, and strangulating sutures is highly desirable. A simple antero-posterior closure of the end of the stump with interrupted fine silk sutures recommended by Dr. Herbert Adams, is used at the Lahey Clinic (Fig. 266). Two sutures are placed at the extremes of the proposed line of section. The distal bronchus is occluded with a heavy tie to avoid further drainage from the specimen. The field is walled off, the suction apparatus made ready, and the bronchus is opened about 0.5 cm. The first suture

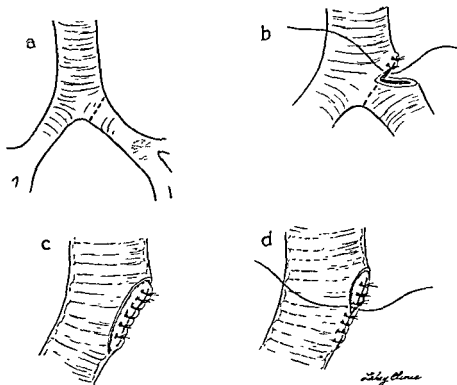


Fig 266 —This shows the method used at the Lahey Clinic for many years to close the bronchus. The second layer (d) is no longer considered essential, but the stump should be covered with pleura if possible. (Reproduced from the Lahey Clinic Bulletin, 1942) .

of fine silk on a French needle is placed and tied. The bronchus is further transected to allow placement of the next suture which is also tied, and this procedure continued until the closure is completed. There should be minimal soiling and absolutely no intrabronchial aspiration of blood. Furthermore, there is very little change in the depth of anesthesia because the circuit is scarcely disturbed. Section is carried out as close to the carina as possible. This leaves the specimen hanging by the inferior pulmonary vein and ligament. Two ties are placed on this vessel close to the pericardium and the lung cut away, leaving a proximal stump of good length.

An attempt is then made to remove all lymph nodes from the mediastinum, which have not already been removed with the specimen, especially in the peritracheal area and under the carina. Finally, great care is taken to pleuralize the mediastinum, especially the bronchial stump. Despite every effort to preserve pleura it is not always possible to close the mediastinum, especially on the left side. As a rule, however, sufficient pleura is available to cover the bronchial stump.

QUESTION OF DRAINAGE

Most surgeons do not believe that drainage of the thorax after total pneumonectomy is necessary. In all these cases we place a catheter in the chest cavity, with dependent drainage under a water trap without suction. This is done to avoid mediastinal shift. The latter may occur suddenly or develop insidiously without its presence being realized until irreversible cardiorespiratory damage takes place. If suction is not applied, very little fluid is lost. We have had no cause to regret this procedure.

SUMMARY

Many serious technical problems may arise in the course of a total pneumonectomy. Some of the measures which we have found useful in dealing with these difficulties are described.

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CARCINOMA OF THE BREAST: TECHNIC OF RADICAL MASTECTOMY

SAMUEL F. MARSHALL

Since the introduction of radical surgical treatment for cancer of the breast by Halsted and Willy Meyer over fifty years ago, radical mastectomy has been the most effective method of treatment of this condition. We have employed the Halsted method of radical mastectomy at the Lahey Clinic for a number of years and, although this method has been modified somewhat, it essentially follows the basic principles laid down by Halsted in the development of this operation. Both Halsted and Willy Meyer emphasized the need for the removal of the breast, pectoral muscles and the tissues of the axilla in one block. The operation should consist of excision of the breast together with the skin over the entire breast, excision of both pectoral muscles and complete resection of the lymph nodes and areolar tissue of the axilla. During the past ten years, however, in addition to radical mastectomy, we have employed deep roentgen therapy postoperatively, which we believe has aided materially in increasing the five-year survival rates after operation. Before the employment of irradiation therapy only 38.6 per cent of all patients having radical mastectomy (this included those with and those without axillary node involvement) survived operation five years or more. Hare and I have reported on the results of this combined treatment for the first five-year period. In spite of the high incidence of involvement of axillary nodes, there was material improvement in the five-year survival rates with the combined treatment. This rate had risen from 38.6 per cent to 52.1 per cent for the entire group in spite of the fact that 62 per cent of these patients had metastases to the axillary nodes at the time of operation. Of the group without axillary involvement 75 per cent survived for five years and of those with axillary involvement at the time of radical mastectomy 37 per cent were alive and well at the end of five years.

While the value of x-ray therapy combined with radical mastectomy may be a debatable question in the minds of some surgeons, in any case it is our opinion that there has been definite improvement in the results of treatment of cancer of the breast by this combined method, but we believe that further information must be collected from a much larger group of patients treated in a similar manner over a long period of time before any definite conclusions can be drawn. It must be emphasized, therefore, that radical mastectomy still is the most important method of

treatment, but that postoperative x-ray therapy is also a valuable adjunct to radical surgery.

In an effort to permit earlier application of x-ray therapy we have been more conservative in removing skin over the chest wall during the radical operation in order that primary closure can be done and radiation treatment started immediately after operation. Halsted emphasized the importance of wide removal of skin and covering the chest defect with a Thiersch graft. It is evident from our experience with more conservatism in regard to skin removal that the frequency of development of local recurrent growth has not increased as might be expected from previous reports in which wider removal of skin was thought to be absolutely necessary. Lewis and Rienhoff, in an article from Johns Hopkins, reported that local recurrences after Thiersch grafts took place in 30.1 per cent, and after a closed plastic procedure, in 39.7 per cent. In the group of 238 cases that we studied in which radical mastectomy was carried out and postoperative radiation therapy was given, only 8 per cent of these patients had recurrence of malignant disease in the scar area, supraclavicular and axillary regions, and this, too, in a group of which 62 per cent showed secondary malignant involvement in the axillary nodes at the time of operation. In view of this, we have been more conservative in the amount of skin removed at the time of radical mastectomy, we rarely remove more than 5 or 6 cm. of skin beyond the edge of the palpable malignant tumor. In the majority of cases plastic closure of this wound has been carried out. Only occasionally has a Thiersch graft proved to be necessary.

We have not employed simple mastectomy routinely. It is used occasionally only as a palliative measure in removing an ulcerating, advanced malignant growth and, in addition, x-ray therapy is employed as a palliative measure. Occasionally it is necessary also to use simple mastectomy in elderly individuals who are poor surgical risks or patients who have serious cardiac disease or other debilitating diseases that would make a radical mastectomy hazardous. Since a large percentage (37 per cent) of patients with involvement of the axillary nodes can be free of the disease for a period of five years or more, radical mastectomy should be utilized for all patients if at all possible. Simple mastectomy is of no value for those patients who have involvement of the axillary nodes.

We have not confined our treatment of cancer of the breast to a selected group of cases that might possibly present a more favorable prognosis. Radical mastectomy is employed in all cases in which the cancer is still confined to the breast and to the corresponding axilla. The principal contraindications to radical surgery are the presence of distant metastatic tumor, involvement of the lungs, pleura or bones or extension to the supraclavicular nodes or to the opposite breast.

Anesthesia.—Many types of anesthesia have been used but we have gradually come to employ nitrous oxide and ether anesthesia, which can be continued over a long period of time without serious difficulties arising from the anesthetic agent. At the beginning of operation an intravenous needle is placed in the long saphenous vein in either ankle; this permits medication, fluids or blood transfusion to be given during the operation. It is much safer to provide for intravenous medication

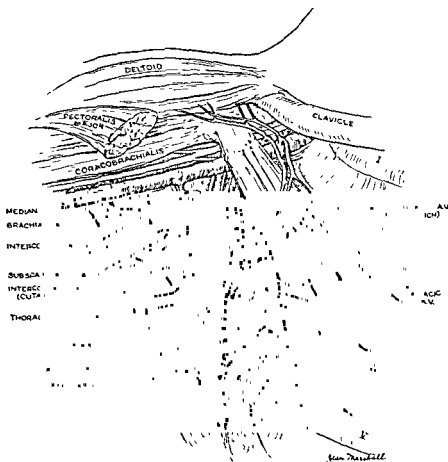


Fig 267.—The anatomy of the axilla. The relationship is shown of the pectoral muscles to the vessels and nerves encountered in axillary dissection for radical mastectomy.

early rather than to wait until shock develops and then attempt to find a vein in order to introduce fluid or blood.

Incision.—The type of incision employed in the clinic is a simple encircling incision with a vertical extension above and below the breast, which in the majority of cases permits ready access to the contents of the axilla and chest wall. Many types of incision for radical removal of the breast have been employed and perhaps all have proved useful and each is advantageous in the hands of the particular surgeon who is accustomed to his own type of radical mastectomy. The type of incision in a

large measure depends upon the location of the tumor in the breast. We have not used the incision which Halsted described in his earliest reports; this incision extends out upon the arm and produces a band of scar tissue across the axilla, thus interfering materially with restoration of arm motion. A simple transverse incision described by Stewart is often useful. Although exposure of the axillary contents is not quite as complete as with the vertical incision, thorough dissection of axillary contents can be made and this incision permits an extremely easy plastic closure of the wound, and heals readily. It is a particularly valuable type of incision for tumors located in the extreme lateral borders of the breast.

*Greenough's arrowhead incision*⁵ permits an excellent approach to the axilla and is a valuable type of incision for those tumors which arise high in the axillary extension of the breast.

Operation.—The operative field is cleaned with zephiran, the skin of the affected side is painted well beyond the midline anteriorly and also onto the back, and the arm also is painted with zephiran to the elbow. The arm is abducted and outstretched on a narrow arm board. The arm usually can be fastened to the arm board since there is little occasion for changing its position during the operation. The skin incision is outlined about the breast and an incision is carried through the skin to the subcutaneous tissue and fat (Fig. 268). The skin incision is extended above the breast toward the shoulder to the level of the clavicle and below, about 7 or 8 cm. distal to the inframammary fold of the breast. The lateral skin flap is dissected first, removing all fat and subcutaneous tissue; nothing but skin is left in the flap.

The dissection is begun at the lower end of the incision and is carried down over the abdomen until the fascia over the rectus and external oblique muscles is exposed. The incision is then carried laterally until the edge of the latissimus dorsi is exposed, this dissection being carried toward the shoulder, exposing the edge of the latissimus dorsi up to the edge of the pectoralis major muscle and beyond, over the muscle to the clavicle. All bleeding points are ligated with fine black silk which is used as ligature material throughout the operation. The medial skin flap is dissected similarly, the dissection being carried from below upward and to the midline of the sternum up to the level of the clavicle. At the upper end of the incision the fascia of the pectoralis major is exposed below the clavicle, and both the clavicular and pectoral portions of the pectoralis major muscle may be removed. If the tumor is not located in the upper half of the breast or is not extensive, however, the muscle may be split between the costal and clavicular portions, which makes the removal of the pectoralis major muscle much easier and less hemorrhagic (Fig. 269). The splitting of the muscle is carried to the insertion of the pectoralis major muscle on the arm and the tendon of the pectoralis

major muscle is divided near its attachment to the humerus and retracted medially over the chest wall. By medial retraction of the pectoralis major muscle, the coracoclavicular fascia covering the pectoralis minor muscle and the axillary vessels and contents are exposed. The

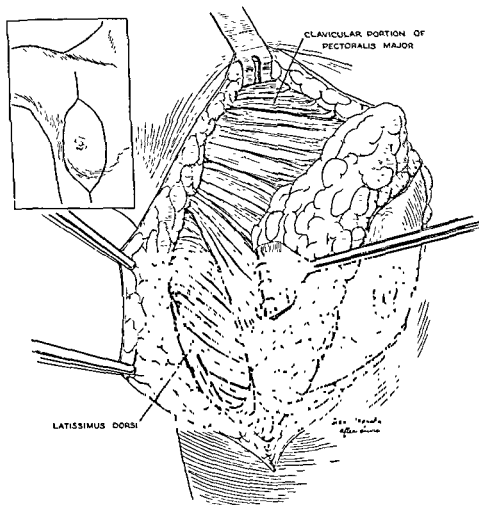


Fig 268 —The type of breast incision used is shown in the insert. It consists of an en-circling incision about the breast and its tumor, the incision is extended vertically above and below the breast. Following the outlining of the incision, the medial and lateral skin flaps are dissected away, exposing the latissimus dorsi laterally and the pectoralis major muscle. The breast is retracted medially during this dissection. The dissection is carried downward, exposing the sheath of the rectus muscle, and extends above over the insertion of the pectoralis major muscle onto the humerus. The line of division between the clavicular and pectoral portions of the pectoralis major muscle is clearly seen at the upper end of the incision.

coracoclavicular fascia fuses with the sheath of the axillary vessels, blends medially with the fascia covering the first and second intercostal interspaces, invests the pectoralis minor muscle and continues laterally to join the axillary fascia.

The coracoclavicular fascia is incised with a knife and the pectoralis minor muscle is exposed (Fig 270). This muscle is dissected up to its point of insertion at the coracoid process and divided and retracted down and medially. Then the removal of the pectoralis major and minor

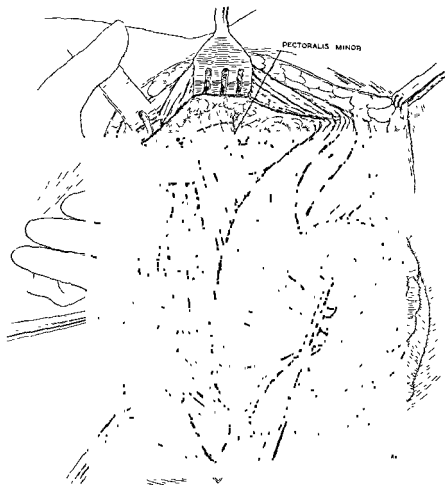


Fig 269 — The pectoralis major muscle has been divided at its insertion upon the humerus and is retracted medially. The pectoralis minor muscle is exposed, its body is dissected cleanly and the point of division at its insertion on the coracoid process is seen. Division of the pectoralis minor muscle exposes the entire axilla for a clean dissection of its fat and node elements.

muscles together with the breast mass from the chest wall can be proceeded with, beginning above at the clavicle and proceeding downward onto the rectus sheath. If tension is kept on the pectoral muscles the perforating branches of the internal mammary vessels are readily seen and can be clamped, divided and ligated. Very little bleeding occurs if

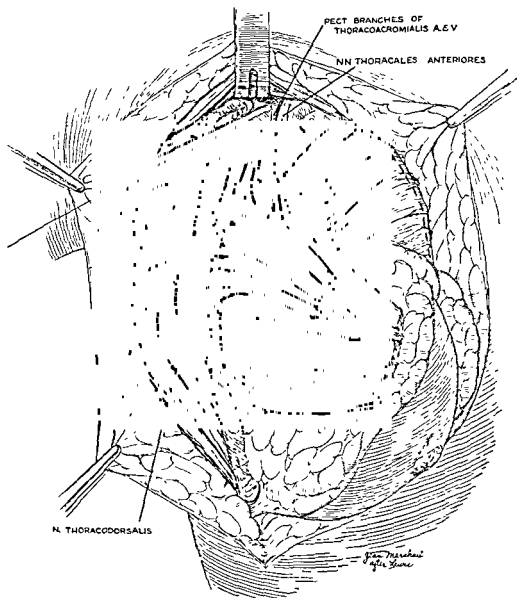


Fig. 270.—The coracoclavicular fascia has been incised, exposing the subclavian and axillary vessels, with all of their branches. The areolar tissue over the vessels is stripped cleanly from the medial end of the clavicle outward along the axillary vessels. The fat and areolar tissues over the brachial plexus are also dissected cleanly and this sharp dissection with removal of lymphoid and areolar tissue is carried out into the axilla. As each vessel is clamped and divided, it is tied immediately with fine black silk. Note the dotted line which illustrates the line of severance of the pectoralis major muscle from the thoracic wall. The entire mass consisting of breast, muscle and fatty tissue is retracted laterally to complete the dissection from the chest wall. This mass is removed *en bloc*, together with all the gland, areolar and fatty tissue of the axilla.

these vessels are exposed and secured before they are torn and divided. As the sheath of the rectus and the external oblique muscle are approached, a portion of the rectus sheath is removed together with the

muscle, exposing the fibers of the rectus muscle. The mass of skin, breast and pectoral muscles can then be retracted laterally and stripped from the chest wall. If a little tension is kept on the mass, the operation is bloodless and the mass can be separated cleanly from the ribs, intercostal muscles and serratus muscles. The dissection is continued to the junction of the posterior and lateral walls of the axilla, removing all fatty tissue, until the border of the latissimus dorsi is reached. The dissection is continued along the edge of this muscle.

Following the removal of the pectoral muscles, the axillary contents are completely exposed and the loose connective tissue, fat and embedded lymph nodes are removed by sharp dissection with a knife. The subclavian vein is exposed at its highest point beneath the clavicle and all of the lymph nodes, areolar tissue and fatty contents are cleanly removed by sharp dissection from the subclavian and axillary vessels. The mass of areolar and gland tissues is removed from above downward, dissecting close to the vein and ligating all vessels immediately with fine black silk to prevent the clamps from being torn from the vein by their own weight and to remove them from the operative field. All tissue along the subclavian and axillary vessels as well as over the brachial plexus is removed cleanly. As the breast mass and muscle mass are retracted laterally during the dissection, the intercostobrachialis and intercostalis nerves which emerge below the second, third and fourth ribs are exposed and divided. Just posterior to these nerves the long thoracic nerve, which lies closely along the chest wall and innervates the serratus, is exposed. This can readily be identified and should be preserved along the chest wall.

The dissection is carried laterally until the subscapular vessels and long subscapular nerve are exposed. The vessels are divided and ligated and the subscapular nerve, if involved with the tumor and lymph nodes, should be removed also. Usually, however, it can be preserved but its removal does not appear seriously to disturb the motion of the arm. We have frequently removed it without disability in those cases in which many nodes are found along the course of the nerve.

The mass of breast and muscle tissue is now retracted medially by an assistant and, with gentle traction, the vessels along the exposed edge of the latissimus dorsi are readily seen, clamped, divided and ligated, thus preventing troublesome hemorrhage which may greatly interfere with clean dissection of the axilla. The areolar tissue and nodes between the latissimus dorsi and chest wall are thoroughly cleaned from the muscle and chest and removed, together with the entire block of breast and muscle tissue (Fig. 271).

The wound is carefully inspected for bleeding and all bleeding points are ligated so that the wound in most cases is thoroughly dry. During

the operation the chest wall is covered with moist, warm gauze pads to prevent undue exposure and consequent shock. If dissection is carried

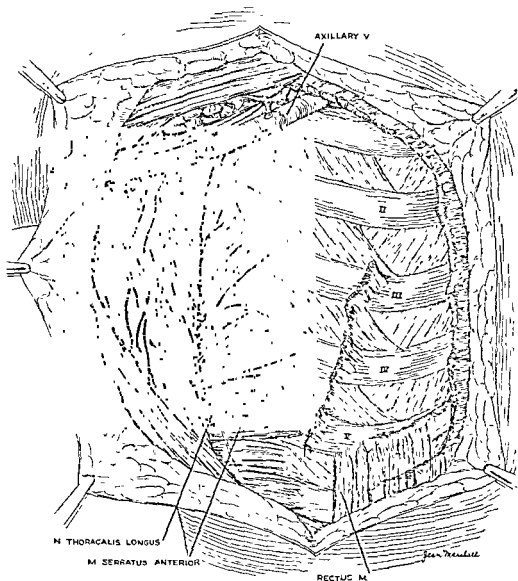


Fig 271.—The completed operation. The subclavian and axillary vessels have been stripped cleanly of their fatty and areolar tissue. Note that the fascia of the rectus muscle has been removed and the chest wall cleaned thoroughly, allowing the thoracalis longus and thoracodorsalis nerves to remain. All of the fat, glandular and areolar tissue are removed between the latissimus dorsi and the serratus muscles. This completes the operation. Careful hemostasis is obtained before wound closure and the skin edges are approximated with interrupted sutures of fine black silk.

along methodically, all vessels can be exposed, hemostasis obtained and blood loss can be kept at a minimum so that shock rarely occurs.

The wound is closed by approximating the skin edges with interrupted sutures of fine black silk. No subcutaneous sutures or retention sutures

are used and trauma to the skin flap is carefully avoided so that there is no further interference to the already much decreased blood supply. Following closure of the wound, the skin flaps are allowed to fall naturally in place over the axillary defect and are held in place by pressure from soft fluffed gauze and dressing pads. The arm is bandaged firmly to the side of the chest and the forearm is placed across the body in a sling. We do not employ drainage of the axilla and in the majority of cases healing takes place primarily without the accumulation of serum. If serum does occur it may be aspirated easily with a sterile needle introduced between the stitches and, if careful hemostasis has been carried out during the operation, there is very little development of serum. The skin edges can be approximated in the majority of cases and plastic closure of the wound obtained, but should this not be possible we do not hesitate to apply a Thiersch graft to the remaining exposed portion at the time of the radical mastectomy. We prefer plastic closure, however, as stated previously, so that postoperative x-ray therapy may be started as early as possible.

Postoperative Measures.—The patient usually is able to sit in a chair by the end of the second day. The arm is released within twenty-four hours, partly abducted but fully extended by passive motion. This can be accomplished without great distress to the patient. The range of motion is easily obtained by early passive motion of the arm. There has been no ill effect on wound healing and no separation of skin flaps from the chest wall as the result of early motion.

There are few cases, indeed, in which radical mastectomy cannot be done with a great margin of safety. In a group of 238 consecutive radical mastectomies there was only one postoperative death which resulted from coronary occlusion. As stated previously, patients are allowed up in a chair as early as possible, usually by the end of the second day, encouraged to exercise the arm early, and usually before radiation treatment is started almost all patients have practically complete range of arm motion.

Radiation treatment with deep x-rays is usually started within ten days to two weeks after operation, when we have deemed the healing of the chest wound to be satisfactory. Treatment is delivered to the scar, the axilla and the supraclavicular areas. As an initial dose, 300 roentgen units is given to each port, treating one portal daily for three days. Following this, each portal is treated daily with 100 r until 2400 r has been delivered to each of three portals, for an over-all dosage of 7200 r.

There has been no material interference with wound healing by giving this deep x-ray therapy soon after operation. Only moderate skin reaction to x-rays has occurred and pulmonary changes such as radiation

pulmonitis have not resulted. Mild erythema and desquamation do occur following this form of treatment, but they are limited to the axilla and the scar area; they usually reach a peak within fifteen to twenty-one days and the erythema fades gradually until the skin is normal, except for pigmentation, at the end of eight weeks.

After radical mastectomy and deep x-ray therapy for carcinoma, the course of these patients is followed at regular intervals and they are examined once every three months during the first two years. After the first two years, they are examined at six-month intervals until the end of five years. This examination should include fluoroscopy of the chest and, in the event of any suspicion of recurrence in the form of chest or skeletal metastases, roentgenograms of the skeletal system or of the chest are obtained.

The postoperative five-year survival rates are good, there being 75 per cent five-year survival of those patients without involvement of nodes and 37 per cent five-year survival of those who have involvement of nodes.

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TECHNIC OF SPLENECTOMY

FRANK H. LAHEY

In a recent paper on the indications for splenectomy, published by myself and John W. Norcross of this clinic, we divided the groups of the conditions for which splenectomy should be considered into three. It might be well to mention these groups because various types of splenectomy, and there are really three approaches to this operation as related to its technical performance, are called for in these three groups.

The first group of cases consists of those conditions directly within the spleen or the result of trauma, or those rare cases in which tumors are limited to the spleen, such as occur sometimes in Hodgkin's disease, or with lymphomas. This group also contains those cases that we have discussed previously in which the spleen is removed together with the stomach to increase the radicalness of the procedure of total gastrectomy for carcinoma of the stomach, and a few of the cases in which the spleen is involved in diaphragmatic hernia or in which better exposure is needed for resection of the lower end of the esophagus to the diaphragm and thorax.

The second group of cases is represented by those patients in whom the splenic effect is upon bone marrow, notably the primary neutropenias and primary idiopathic thrombocytopenia. Included in this group also are those patients with hemolytic anemia with their abnormal spherocytic type of red cells in which the spleen with its large reticulo-endothelial system serves as an abnormal destruction center for them. Also included in this second group are those patients with the panhematocytopenias, that peculiar state in which because of splenic enlargement any one or all of the three splenic effects producing blood dyscrasias may be present, that is, depression of the bone marrow regions from which arise granulocytes, and of the bone marrow portion (megakaryocytes) from which arise blood platelets, and also blood conditions which produce hemolytic anemia.

The third group of cases in which splenectomy is to be considered is that related to congestive splenomegaly, sometimes called Banti's disease. This group of patients has been divided arbitrarily into three grades: the very early grades represented only by moderate blood changes and splenomegaly; the second group represented by blood changes, splenomegaly and esophageal varices, and the third group represented by cirrhosis of a fairly advanced character together with ascites. It is in this group that one so often sees perisplenitis with such vascularized adhesions about the spleen that the technical difficulties of

splenectomy become abnormal and the hazard of the operation is much greater.

It is to be recalled that in a recent report of 83 splenectomies done in this clinic for various diseases, the only 2 fatalities occurring in the entire group resulted from splenectomies done in the third stage of congestive splenomegaly.

One must remember that, in the diseases for which splenectomy is done, these splenic effects occur not only as chronic splenic processes but that they possess acute phases in which the accomplishment of a splenectomy is fraught with great hazards because of the precarious condition of the patient which often necessitates abandoning technical niceties in favor of speed, thus resulting in a less tidy but more rapid operation.

In discussing anesthesia for splenectomy we must admit to certain prejudices in this clinic in favor of spinal anesthesia. These are based upon an unusually large experience with spinal anesthesia and the fact that all anesthesia in this clinic is given by permanent, full-time physician-anesthetists who are devoting their lives to it. Spinal anesthesia, furthermore, does have the advantages of allowing for a good exposure of splenic pedicles, and of providing a quiet abdomen, an undistended intestine and adequate relaxation.

We have no debate with anyone concerning the choice of anesthesia, agreeing that ethylene, cyclopropane or ether anesthesia, perhaps combined with curare, or any other form of anesthesia that is not contraindicated by the serious condition of the patient if he is in an acute phase of splenic disease, is entirely satisfactory.

It is to be recalled that, particularly in those patients who have large spleens, a good-sized fraction of the entire volume of blood within the body will be in the spleen, and measures, particularly in sick patients, should be at hand for substitution for this loss by transfusions.

It used to be stated that by means of the injection of epinephrine into the spleen its blood could be expelled into the general circulation and the size of the spleen decreased. It is the feeling today of our hematologists that this is better left undone and that it is better to replace the blood loss with normal blood rather than with that which contains undesirable effects of hypersplenism.

Probably there will always be a great variation in the type of incisions employed for splenectomy. We have consistently employed long, left rectus incisions and with good relaxation have never felt in any way limited for exposure. It has never been necessary for us even in the very large spleens to make a transverse incision or to employ incisions of an oblique character. This is, however, largely a matter of taste, and we do not say this with any criticism of other types of incisions.

With the abdomen open, we have made complete examinations of the abdominal contents, have investigated the size of the spleen, its mobility, the probable ease with which it can be delivered, and if splenectomy is being done for one of the four blood states—thrombocytopenia, primary neutropenia, hemolytic anemia or panhematocytopenia—a general inspection of the abdomen and the omentum is made for accessory spleens. This is extremely important because accessory spleens are most easily found at the time of the splenectomy.

There are two types of splenectomy and one further technical step relating to the control of its blood supply by ligation of the splenic artery at its origin.

It is to be recalled that the spleen possesses no real suspensory ligament and that it remains in its position in the left hypochondrium because it is partly extraperitoneal and is suspended by a few ridges and folds of the posterior parietal peritoneum. In one type of splenectomy, that is, the type which must be done rapidly, either because of the patient's condition or because of the indication for the splenectomy, such as trauma resulting in ruptured spleen, the posterior attachment of the spleen to the parietal peritoneum is rapidly separated by the finger, the spleen is turned from below upward, its attachment to the stomach by the vasa brevia ligated and the entire spleen turned out onto the abdominal wall, as shown in Figure 272.

Because the splenic artery and vein run along the upper edge of the pancreas, if one turns the spleen to the right and outward, the tail of the pancreas will be delivered with it and unless one is exceedingly careful, mass ligatures or clamps placed upon the pedicle of the spleen, particularly if there is alarming bleeding, can very well include the tip of the pancreatic tail and result in later pancreatic fistulas.

By far the most satisfactory type of splenectomy is the deliberate splenectomy on a patient not in an acute phase of the four blood states for which splenectomy is so satisfactory—hemolytic anemia, idiopathic thrombocytopenia, primary neutropenia or either primary or secondary panhematocytopenia. When splenectomy is not done in any of these conditions in patients in an acute phase of the disease or in a state of crisis, time is not important but a dry field, wide exposure, good visualization and thorough search for accessory spleens are of the utmost importance.

The gastrocolic omentum is ligated, tying all the vessels close to the greater curvature of the stomach including those that go over to the spleen as the greater curvature swings around to the diaphragm. The attachment of the splenic flexure to the diaphragm is so liberated that the splenic flexure can be dropped, any communications between the spleen and the splenic flexure are severed and the lesser peritoneal cavity

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from its peritoneal attachment to the posterior abdominal wall can then be carefully controlled, the field can be made completely dry, the gastrocolic omentum can be restored to the greater curvature of the stomach and any accessory spleens found and removed (Fig. 273).

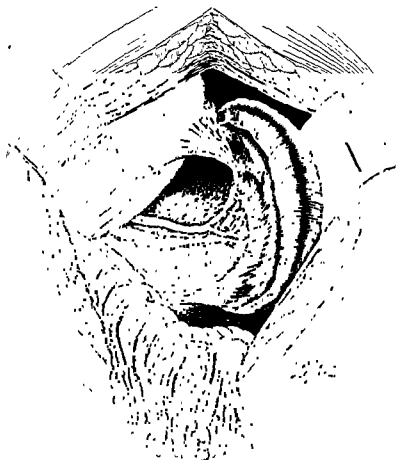


Fig 273 —The deliberate type of splenectomy is demonstrated in which the splenic flexure is mobilized down where the gastrocolic omentum is completely separated from the greater curvature of the stomach, and the lesser peritoneal cavity is widely opened. By means of this deliberate exposure, the vessels running between the hilum of the spleen and the greater curvature of the stomach can be separated, the splenic vein and splenic artery accurately visualized and individually ligated, the spleen then lifted from its bed in the left upper quadrant and all vessels on the posterior abdominal wall accurately controlled.

This is by far the best surgical approach to splenectomy, permitting such a wide exposure, complete visualization and anatomical demonstration of all structures. We have employed it in all deliberate splenectomies for hemolytic anemia, idiopathic thrombocytopenia and primary or secondary panhematocytopenia.

With the lesser peritoneal cavity exposed, one can search along the course of the ureter, particularly when the splenic flexure has been dropped, and one can look over and above the pancreas, over and above the kidney and in the gastrocolic omentum and greater omentum where accessory spleens are so often found. In one of our recent splenectomies

there were four accessory spleens, so one must not be satisfied merely by the discovery of a single accessory spleen

The remaining type of operation for splenic diseases is that employed when very well vascularized perisplenic adhesions are present, particularly in the third stage of Banti's disease. I have never had to deal with more distressing bleeding than that accompanying unwise attempts at removing the spleen in patients with perisplenitis, particularly when these adhesions were present, as they so frequently are in patients in the



Fig 274 --In this illustration the anatomy is demonstrated diagrammatically through the gastrohepatic omentum and ligation of the splenic artery may be seen close to its origin. As stated in the text, this is an extremely valuable measure in patients with heavily vascularized perisplenitis who are in such a serious condition that nothing more than this is considered advisable.

third stage of Banti's disease with increased venous tributaries. The venous bleeding in these cases is most difficult to control. It is in these cases that we believe it is wiser to ligate the splenic artery at its origin to the gastrohepatic omentum or, by detaching the gastrocolic omentum, to turn the stomach up and expose the splenic artery at its origin (Fig 274).

There are two or three points that I would like to make in connection with splenectomy. One is that, with the rapid removal of the spleen in

emergency cases, there is often a subdiaphragmatic hematoma which can become infected and produce a subdiaphragmatic abscess as a result of the oozing. In those cases in which oozing does occur, it may be controlled by introducing a cigaret drain with a good deal of gauze in the end and bringing it out through a counterincision in the left loin, particularly if the oozing occurs in the left upper quadrant area, now denuded of peritoneum, and cannot be satisfactorily controlled.

Another point that we have learned, particularly in the case of splens with large veins, is that one should not attempt ligation of the splenic vessels along the upper edge of the pancreas. If the splenic vessel is to be ligated, the artery should be ligated either at its origin or at the tip of the pancreas and the hilum of the spleen. Attempts to ligate the splenic vessels midway between these points where the vessels run along the upper edge of the pancreas will often be disastrous because the splenic vessels are frequently partly buried in the pancreas and to it, and it is difficult at this midpoint to get the ligatures around the splenic vessel.

Whenever a deliberate splenectomy can be done with a good exposure, it will be possible to so control bleeding that hematoma should not develop.

In previous discussions of this subject we have called attention to the fact that splenectomy provides an excellent direct anterior exposure of the left adrenal gland. Following deliberate splenectomy the adrenal can be seen resting on the top of the left kidney.

We believe that it is again worth while, as we have done in our article on splenectomy, to call attention to the opinions of our hematologists that since splenectomy is without undesirable postoperative effects, or at least any demonstrable effect, and since we have performed 83 splenectomies and only 2 fatalities which occurred in advanced cases of Banti's disease when it was probably unwise to perform it, it is safe in taking the position that in cases of chronic enlargement of the spleen, provided the patients do not live in districts where such other tropical diseases are common, and provided there are no demonstrable causes of the enlargement, splenectomy as a prophylactic measure is justifiable. It is our opinion that congestive splenomegaly will develop in a definite percentage of patients with splenomegaly; there is always the hazard of the development of panhematomatous splenomegaly which is the result of tumefaction of the spleen, promoting the hypersplenic effect. Prophylactic splenectomy may be of value in these cases.

TOTAL GASTRECTOMY

FRANK H. LAHEY

It was not so very many years ago that total gastrectomy was a surgical feat, something to thrill one as a new accomplishment of surgery. I know about this feeling because of my early interest in developing this operation and our early experiences with it.

The mortality of this operation, as one would expect, was almost at a prohibitive figure in our early experiences with it. This was almost bound to happen because of the newness of the procedure, and the mortality was related, as is true in so many pioneer efforts, not only to technical methods but, even more closely, to a poor selection of cases. I am sure that in our own early experience with this operation the selection in many cases was based on poor judgment. We had not learned various determining points upon which one could decide whether or not total gastrectomy was justifiable. Technical considerations undoubtedly played an important part in the early mortality of total gastrectomy, but these were progressively overcome as experience with it increased in our own clinic and elsewhere, and the methods were published, until now the operative mortality in this formidable procedure is within reasonable limits. In our early experience the mortality was over 40 per cent, but in the last 67 cases it was 13.6 per cent.

INDICATIONS

It is obvious that this operation will be done only on patients with extensive malignancy and so, before discussing the technical steps of total gastrectomy, it will be of value to discuss briefly some of the points on which the decision for or against a total gastrectomy may be based.

Total gastrectomy will be done for patients with malignancies of the stomach of the carcinomatous type, of the lymphomatous type and of the leiomyosarcomatous type. On the basis of an experience now with 115 patients on whom we have performed the operation, I would like to set down how we go about determining whether or not its use is justifiable in the case of a given patient with gastric malignancy. Before discussing these points I would like to say that the longest survival of a patient upon whom I have done total gastrectomy for carcinoma is seven and one-half years. In this case there was such extensive involvement of the stomach with nodes extending up along the lesser curvature, well down on the origin of the gastric artery, that my conscience bothered me considerably after I was well into the operation over whether or not I should have undertaken it. This patient is completely well, back

at work now at the end of seven or eight years, and one can presume with reasonable assurance that he is cured. In addition to this case, there have been several other patients in this series who have survived six and seven years, and one patient whose condition seemed quite hopeless when he was first seen survived twelve years.

The decision for or against the performance of total gastrectomy is formed in a manner not unlike that for or against subtotal gastrectomy for carcinoma of the stomach about which I have written previously, giving the criteria of operability. The decision is made with the abdomen open. The same routine examinations should be employed as are employed in any malignant condition of the stomach, with a few added steps of investigation to settle the question of whether or not total gastrectomy is worth while. The pelvis should be searched for gravity metastases, the omentum carefully palpated, both lobes of the liver palpated for possible metastases, the transverse colon should be turned up and the root of the mesentery of the transverse colon thoroughly palpated and inspected for gravity metastases from the posterior wall of the stomach in the lesser peritoneal cavity, the gastrohepatic and gastrocolic omentum should be thoroughly searched for possible extension, and the angle made by the greater curvature of the stomach and the inner aspect of the duodenum where the head of the pancreas rests at the pylorus should be thoroughly investigated for the possible presence in this region of metastatic nodes which cannot be removed. In addition to these investigations, if there is any question about an extensive lesion involving the posterior wall of the stomach becoming adherent to the pancreas, the omentum should first be carefully detached from the transverse colon, as shown in Figure 275, by means of which the entire lesser peritoneal cavity is exposed to view. Any invasion of the pancreas then becomes demonstrable, and the posterior aspect of the stomach up to the esophagus, as well as the anterior aspect, can be well inspected and palpated. If the lesion has involved the pancreas, one can see whether or not it has involved the tail so that the tail of the pancreas may be removed with the lesion, or whether it has become so adherent to the body of the pancreas that it is not removable.

If the lesion has not become adherent to the pancreas one can put one hand behind the esophagus, the other in front, and the chain of nodes running up beside the esophagus can be palpated to determine whether metastatically involved nodes extend up beyond the diaphragm and are involved extensively. It is important to state here that even though a small chain of indurated nodes may be felt running up beside the esophagus to the diaphragm, one must realize that, as soon as both vagus nerves are severed, a large part of the esophagus can be pulled down

from the chest, and the nodes beside the esophagus can be wiped down and removed with the lesion in the course of the total gastrectomy.

One should then palpate the nodes in the gastrohepatic omentum,



Fig 275 —Method of detaching the great omentum from the transverse colon so that the entire lesser peritoneal cavity is exposed. In the actual operation, the spleen is left attached at the two points (x). In this illustration it has been turned down in order to show its blood supply.

One can see from this illustration that the back of the stomach, the back of the esophagus, the left gastric artery and the splenic vessels can be exposed. One can also see that exploration can be done without committing oneself definitely to total gastrectomy. Should the lesion prove inoperable, the operation can safely be stopped at this point.

It may also be noted that the spleen will be left attached to the omentum, and the stomach, spleen, omentum and gastrohepatic omentum will be removed in one block.

particularly when they extend along the lesser gastric artery, because not infrequently this type of malignant extension will progress along the side of the artery so that in some of the cases the lesion will be inoperable because ligation of the left gastric artery will have to be done through a

at work now at the end of seven or eight years, and one can presume with reasonable assurance that he is cured. In addition to this case, there have been several other patients in this series who have survived six and seven years, and one patient whose condition seemed quite hopeless when he was first seen survived twelve years.

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In Figure 277 will be seen the total specimen removed at operation. Such extensive malignant involvement will be present in almost all of the cases in which total gastrectomy is done. This specimen meets the indications described in the previous paragraph.

Incision.—The incision employed for total gastrectomy is, I believe, largely a matter of choice with the exception of the continuation of the incision above the ribs, opening of the chest and opening of the diaphragm.

We believe that the combined approach to certain cancers of the

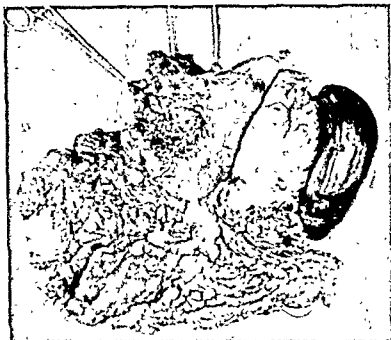


Fig 277 —Specimen of carcinoma of the stomach removed by total gastrectomy. Note that this specimen fulfills the requirements illustrated in Figure 276; it includes all of the omentum, the spleen, the entire stomach and all of the gastrohepatic omentum.

stomach and lower end of the esophagus is generally an advantageous one. In those cases in which the malignant disease is limited to the stomach, however, and a normal esophagus can be freed and pulled down, we have found it advantageous to perform the operation without opening the chest, without the added complication of the combined laparotomy and thoracotomy. We have no hesitancy, however, if it is necessary, to continue the incision above the diaphragm and combine the exposure of the thorax and the abdomen.

We have no feeling regarding the employment by others of oblique incisions, hockey stick incisions, transverse incisions or any other type. We wish only to say that we have performed all of our total gastrectomies without limitation of exposure by means of the long transrectus

incision through the left rectus muscle. This, with good relaxation, undergoes good repair and, if it is of adequate length, does not hamper us in the performance of this operation.

Technical Steps in Resection.—The first technical step in total gastrectomy is the separation of the greater omentum from the transverse colon. This is best started on the right side at the point where the hepatic flexure is attached to the greater omentum. As the greater omentum is separated at this point, as shown in Figure 275, one comes naturally to the developmental line of cleavage by which the omentum is fused with the mesocolon at this point. If one gets started in the proper line of cleavage in separating the omentum from the transverse colon, one can literally wipe the omentum off the transverse colon until the lesser peritoneal cavity is entered, and continue the separation over to the splenic flexure and the spleen so that, with the omentum completely separated from the transverse colon and mesocolon, the entire lesser peritoneal cavity is widely exposed.

With the stomach then turned up, as shown in Figure 275, the entire posterior wall of the stomach is exposed to view, the blood supply of the spleen is immediately under one's finger and can be ligated so that the spleen is mobilized, and one can then see the posterior aspect of the esophagus, the left gastric artery, the diaphragm, and the left lobe of the liver. If at this point the carcinoma is found to have extended further than was originally anticipated, the operation can be interrupted and the abdomen closed without having committed one's self definitely to its completion.

I believe that one of the most important technical steps in total gastrectomy is the complete separation of the omentum so that the entire stomach with the omentum and the spleen attached to it can be so turned up that the posterior aspect of the stomach well up to the diaphragm can be inspected. This is a valuable exposure in determining operability and, as already stated, permits one to terminate the operation if additional evidence of extension becomes available.

The spleen should be left attached to the omentum, its blood supply ligated at the tail of the pancreas and severed so that, as the stomach is removed (Fig 276), there will be one block of tissue consisting of the entire stomach, the omentum, the spleen within the omentum and all of the nodes of the gastrohepatic omentum.

The advantage of splenectomy at this point is that in many of the carcinomas or other malignant growths of the stomach for which total gastrectomy will be done, a set of nodes which is known to exist between the greater curvature of the stomach and the hilum of the spleen will be removed intact.

We have heard and read comments that the removal of the spleen is

unwise in total gastrectomies. I do not mean to be controversial but I believe that it is a poor approach to the problem. In any patient with malignant disease of the stomach of such advanced character that total gastrectomy is settled upon, the operation cannot be too radical. There will frequently be involvement of the nodes that, as I have already stated, are known to exist between the greater curvature of the stomach and the hilum of the spleen, and only by including splenectomy can they be removed.

With the entire omentum and the spleen in it turned up, the next step in the procedure is transection of the duodenum. Before doing this we would do well to remember that, contrary to previous beliefs, carcinoma does spread submucously beyond the pylorus and into the duodenum, as has recently been demonstrated by our pathologists, Drs. Warren and Meissner. For this reason in all total gastrectomies the duodenum should be freely mobilized for the greatest possible distance, down close to where the common duct and pancreatic duct enter it, in order that possibly submucously involved duodenum may be removed as completely as possible.

With the duodenum turned up, the next step is the complete removal of the gastrohepatic omentum. This will require high ligation of all of the small vessels up to the exposure of the left gastric artery. The left gastric artery will require inspection, as already stated, to determine whether the malignant growth has extended so high on its wall that the condition is deemed inoperable. This point must be settled before the duodenum is cut across and can be when the omentum is completely freed, the lesser peritoneal cavity exposed and the entire stomach turned up as shown in Figure 275.

If the left gastric artery is not involved, it is tied at the highest possible level. I have preferred to tie the left gastric artery with No. 2 chromic catgut because it is strong and the first knot does not slip. Hemorrhage from the left gastric artery, if it occurs, is difficult to control, and while it can be controlled, it is technically annoying. With the left gastric artery cut and severed, the complete removal of the gastrohepatic omentum can then be carried up to the point where the lesser curvature merges with the esophagus.

At this point I would like to call attention to a technical step which I published and have employed over the years and which has proved valuable in my hands, that is, the wrapping of the omentum, the stomach and the spleen in a large square of gauze. If one attempts to handle these structures, so many loose ends wander about that they constantly interfere with the technical steps of the operative procedure. Early in my experience I developed the plan of wrapping all of the spleen, omentum and stomach up in a square of gauze, tying this as shown in Figure

278, by means of which everything is then put into a compact bundle and can be held in one hand or by an assistant as the esophagus is freed and made visible for the anastomosis of the jejunum to it

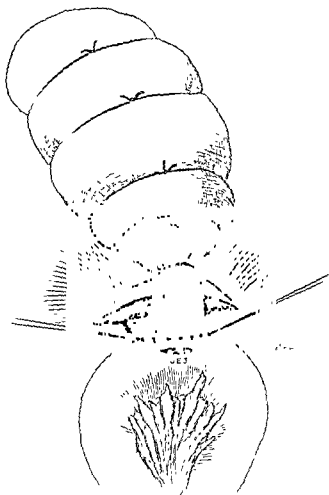


Fig 278 —Method of wrapping the stomach, omentum and spleen in an apron of gauze and tying it with ligatures, shown diagrammatically This makes it possible to manage large specimens with greater ease

Note also as stated in the text, the ligature at the point where the esophagus joins the stomach to prevent spilling of accumulated gastric contents when the opening is made in the esophagus in order to establish the anastomosis.

Note also in this that the opening in the jejunum is small and circular, and is best made, as shown in Figure 281, *a*, by grasping the jejunum with a hemostat, pulling it to a point and excising that point, thus creating a small circular opening. It is again to be recalled that this opening will be larger than is anticipated

The next technical step in the procedure of total gastrectomy is the exposure of the esophagus as it runs through the diaphragm. This can

best be accomplished by severing the nonvascular ligament between the diaphragm and the left lobe of the liver. There will occasionally be small vessels in this ligament but they usually are of no great significance and can be controlled easily under direct vision. With the left lobe of the liver detached (Fig. 279), folded to the right and held there by a wet pad and a deep-bladed retractor, the esophagus as it enters the diaphragm becomes plainly visible. The next step which I developed and published and the most important one, I believe, in cutting the mortality down is the making of a flap of peritoneum as it is reflected over the esophagus, which will later be sutured to the jejunum to suspend the

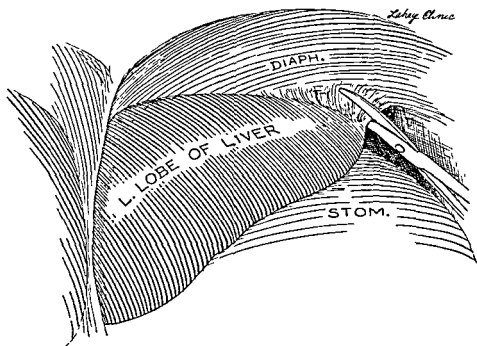


Fig 279 —Method of detaching the left lobe of the liver from the diaphragm by severing its avascular ligaments

jejunum, reinforce the suture line and thus take the weight of the two loops of jejunum off the line of anastomosis. With this flap cut, as shown in Figure 280, the branches of the vagi, the two main front and back or lateral branches, and also other branches become visible. These are cut under direct vision and, as the stomach wrapped in its gauze pad is pulled down, any other branches can be felt as bow strings and may be severed.

Severing of the vagi has been one of the important features in making total gastrectomy easy. As soon as the vagi are severed, a considerable length of esophagus can immediately be pulled down from its position in the diaphragm and above it. So much esophagus can frequently be pulled down by this maneuver or by freeing the esophagus with the

finger within the diaphragmatic hiatus that it can be brought close to the abdominal wall where the suture must be done.

One must remember at this point to ask the anesthetist to withdraw the tube that has been placed in the stomach, first asking him to suction out the contents of the stomach. The tube must be withdrawn up into the esophagus just above the level where it passes through the diaphragm in order that the anesthetist may keep the esophagus con-

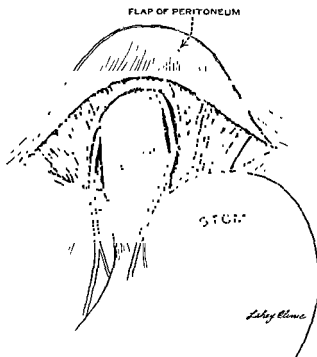


Fig 280 —The flap of peritoneum cut from the front surface of the esophagus and reflected over the diaphragm is diagrammatically shown. This flap of peritoneum will be used to suture to the jejunum, to reinforce the anterior suture line and to take up the weight of the jejunum anastomosed to the esophagus.

This illustration also shows the vagi diagrammatically and how necessary it is to sever nerves before free delivery of the esophagus can be obtained.

stantly clear of its contents when it is opened for the direct anastomosis between it and the side of the loop of jejunum which is to be attached to it.

An extremely important point at this stage, and one that is easily forgotten, is that most of these stomachs, no matter how well they are cleared by suction, still frequently contain a great deal of undesirable liquid and semiliquid material discharged from the carcinoma. For this reason I have found it extremely valuable to tie a double thickness of No. 2 chromic catgut about the point where the esophagus enters the

cardia in order to prevent spillage of gastric contents as the stomach is held up, as shown in Figure 278, and as the anastomosis of the jejunum to it is made.

Esophagojejunal Anastomosis.—With the vagi separated, with any small oozing bleeders, which are frequently attached to the esophagus, found and controlled, and with good exposure, a loop of jejunum is selected at a level low enough so that its length of mesentery will permit it to be brought up anterior to the colon and approximated to the esophagus. We have preferred antecolic anastomoses to retrocolic anastomoses because we want a long loop of proximal jejunum since it is to serve in a considerable measure as a substitute for a stomach and because, to avoid irritating contents of the proximal jejunum and duodenum, bile and pancreatic juice, from passing over the anastomosis between the esophagus and jejunum, a lateral anastomosis is to be done.

We have always placed the proximal loop of the jejunum to the left so that an anastomosis of the proximal loop of the jejunum is started on the left side of the esophagus. I do not believe that this is too important but because we have applied this principle in our partial gastrectomies for ulcer and for carcinoma and because it has functioned so well, we have continued the use of this principle for many years.

The next step in a total gastrectomy is one of the most important, I believe, of all the steps of this operation and that is the introduction of the first posterior layer of silk sutures by means of which the jejunal loop is to be approximated to the back wall of the esophagus. This step is not difficult, but when this first layer of silk stitches is put in, the jejunum is then so high up, so angulated at the point where the esophagus and the jejunum come together that it is difficult to get sufficient exposure to make the first opening in the jejunum and in the esophagus which is to represent the second layer of approximation catgut stitches between the esophagus and jejunum.

It is at this point that I wish to call attention to the maneuver first suggested by Dr. S. F. Marshall of this clinic of introducing long black silk stitches into the jejunum and the esophagus, then opening the jejunum before the approximation of the first layer of silk stitches is completed (Fig. 281, *b*). This maneuver is of great value because the opening in the jejunum can be made before the jejunum is approximated to the back wall of the esophagus by the first row of silk stitches. One thing I would particularly like to warn about—and a mistake that I made in my early experiences with total gastrectomy—is that of making the opening in the jejunum too large. The jejunum is a lax structure, the caliber of the esophagus is not large, and one must be careful lest in making too large an incision in the jejunum the redundant mucous membrane in an aperture of too great size can be troublesome and annoy-

ing (see Fig. 281, a). One must remember also that the original incision in the jejunum when the suture line is completed will be found to be

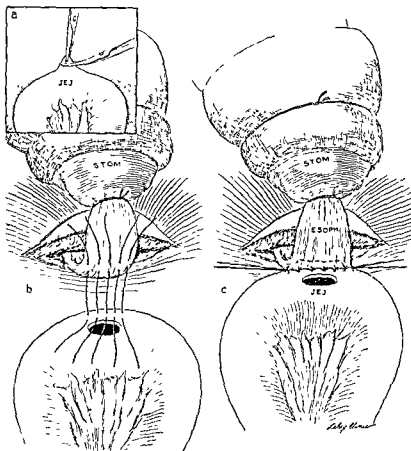


Fig 281 —Plan devised by Dr Marshall in which the long black silk stitches are placed through the jejunum and the posterior wall of the esophagus. These sutures will represent the posterior layer of silk approximation stitches

a, Method of opening the jejunum to avoid too large an aperture and to establish a round opening. It is important that the opening in the jejunum, as stated in the text, is not made too large. It is made *after* the laying of stitches, as shown in b.

b, As stated, the opening in the jejunum is made after the stitches are laid, left long and not tied. Note the ligature of the esophagus at the point where the esophagus joins the stomach which prevents back spillage of gastric contents when the esophagus is opened for the anastomosis.

In c is shown the circular opening in the jejunum, the black silk approximation stitches of the posterior wall tied, and the two lateral stitches retained as traction stitches to insure that the anastomosis is kept wide and is eventually flared out in a trumpet-like fashion. The esophagus will be opened along the dotted line.

considerably larger than one had anticipated it would be. As soon as the opening in the jejunum of proper size has been made, the long black

silk stitches, as suggested by Dr. Marshall, can be tied. This approximates the back layer of the jejunum to the back layer of the esophagus and the transverse opening in the esophagus on the posterior wall which is to be closed by continuous interlocking catgut stitches can then be made.

Perhaps the second most important thing that we have learned from our mistakes with this operation is that a traction stitch between both the left and the right angles of the posterior wall of the esophagus and

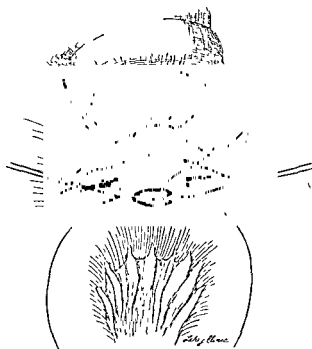


Fig 282 —Note in this diagrammatic illustration the continuous locked stitch of catgut approximating jejunal mucosa to esophageal mucosa. It is an advantage to employ a lock stitch to control ooze and to prevent narrowing

Note also the traction stitches of silk on the side to keep the caliber of the anastomosis large. The ligature is again shown at the point where the esophagus joins the stomach to prevent back spilling of gastric contents when the esophagus is opened

jejunum should be introduced. If one does this, gentle traction can be made on either side by the assistant in order that the posterior interlocking row of continuous catgut stitches which control bleeding is not pulled up too tightly or at least tightly enough to cut through. These lateral traction stitches (Fig. 281, c) keep the esophagus pulled out on either side and thus prevent constriction of the anastomosis. In my own early experiences some of these anastomoses were made so small that they required later dilatation by our esophagoscopist. It is worth noting that, when this anastomosis is completed, if it is done properly, the esophagus will be seen to flare outward as does a trumpet so that the caliber

of the anastomosis is actually greater than the normal caliber of the esophagus itself.

With the first layer of interrupted black silk stitches in and the second posterior layer of interlocked seromuscular stitches completed (Fig. 282), the catgut seromuscular stitch is continued around the corner and over onto the front portion of the jejuno-esophageal anastomosis by means of the Connell in, out and over stitch until the entire circumference of seromuscular catgut anastomosis line has been put in. There

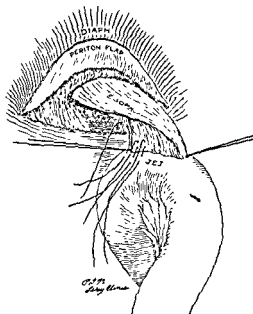


Fig 283 —In this diagrammatic illustration is shown the rotation of the suture line, as in blood vessel suture, making it possible to inspect the posterior layer and to reinforce any weak points with silk sutures. Note also the supporting stitch of silk at the angle between the jejunum and one of the crura of the diaphragm. A similar stitch will be placed in the other crus of the diaphragm, thus providing posterior support to the line of anastomosis.

will be occasional cases in which the anastomosis will be so technically difficult that it must be made with interrupted in, out and over stitches.

As soon as the posterior layers of suture line of silk and catgut are completed, the anterior portion of the esophagus is severed, the stomach, spleen and omentum, wrapped up as they are in an apron of gauze, are then completely detached, making the anterior in, out and over stitch much easier. When the anterior layer of in, out and over catgut has been completed and tied, the anterior interrupted silk stitches are then introduced between the jejunum and the esophagus in a manner similar to that employed for the back row.

As black interrupted silk stitches are placed, it is important that the

two lateral stay stitches that pull the esophagus out laterally be preserved, so that they may be used to rotate the esophagus. One is passed on the right side beneath the anastomosis, then the entire anastomosed line is turned completely over, as in blood vessel suture, until the posterior layer of sutures is plainly visible (Fig. 283). This is extremely important as it permits one to reinforce any weak places. Because these sutures are at times introduced under considerable difficulty, there will be places in which approximation has not been as accurate as can be

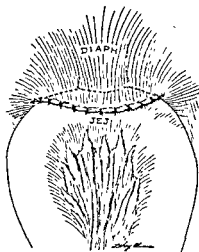


Fig 284 —The completed anastomosis and the flap of peritoneum, previously shown in Figure 280, over the jejunum and attached to it by interrupted silk stitches.

One now can realize that, with the two supporting stitches between the jejunum and the crura of the diaphragm in back and with the peritoneal flap sutured in front, the entire anastomosis between the esophagus and the jejunum is completely supported so that there is no traction weight upon the anastomotic line

It should be remembered, also, although not illustrated in this article, that following the anastomosis of the jejunum to the esophagus a lateral jejunojejunal anastomosis is done lower in the two loops in order to avoid as much as possible the passing up into the esophagus of irritating bile and pancreatic fluids

done with the anastomosis rotated and the posterior layer completely exposed to view. It is possible by this plan to inspect carefully the entire circumference of the esophagojejunal anastomosis to be sure of the accuracy of the anastomotic line of sutures and to reinforce any places needing it.

With two rows of sutures, inner catgut and outer interrupted silk, now completed, the next important step is to pass an interrupted silk stitch through the posterior aspect of the jejunum at the point of anastomosis and through the crus of the diaphragm, the one on the right side of the anastomosis sutured to the right crus of the diaphragm, the one on the left side sutured to the left crus of the diaphragm. The anastomosis is then turned down and the flap or apron of peritoneum which

I first described in 1938 is pulled down and sutured, as shown in Figure 284, to the jejunum, thus covering the suture line completely but, most importantly, suspending the anastomosis posteriorly by the jejunum to the crus of the diaphragm and anteriorly to the flap or apron of peritoneum that reflects over the esophagus. This maneuver has contributed greatly to the technical success of total gastrectomy, as mentioned previously. Prior to the development of this plan I am sure that, owing to the weight of the jejunum and occasional retching which may follow recovery, there was separation of the suture line. One must remember always that the esophagus as it is anastomosed to the jejunum is not covered by peritoneum, is very friable in character, and for this reason one must be extremely careful that sutures introduced into the esophagus are not tied too tightly and that the unsuspended weight of the jejunum is not allowed to pull on the esophagojejunal suture line.

There is one remaining technical step in the direct end-to-side anastomosis of the esophagus to the jejunum without which I would not feel comfortable and that is the introduction by the anesthetist of a full-sized stomach tube into the lower end of the esophagus where the surgeon with his finger can guide it through the anastomotic aperture into either the distal or proximal loop. This, I believe, is of the utmost importance, demonstrating as it does the adequacy and proven patency of the aperture.

Jejunojejunostomy.—In approximately the first 30 total gastrectomies done in this clinic, no jejunojejunostomy was employed but at the suggestion of Dr. Marshall who has performed a number of these total gastrectomies and with the agreement of the other surgeons in the clinic who have employed them, jejunojejunostomy has now been employed regularly in all of the total gastrectomies. We feel that it definitely improves the postoperative recovery and avoids the passage of irritating duodenal contents, bile and pancreatic fluid into the lower end of the esophagus, there to cause, as it used to so frequently, esophagitis. We have been opposed to the employment of jejunojejunostomy in *subtotal* gastrectomies for ulcer and for several years have not used it. In this procedure we want all of the alkaline jejunal contents to be returned into the stomach to produce as much neutralization of gastric acidity as possible. When, however, the entire stomach has been taken out as in total gastrectomy, there is every reason for employing jejunojejunostomy, particularly that of sidetracking the irritating duodenal contents.

Completion of the Operation; Closure of the Wound.—When the operation is now completed, the proximal loop of jejunum at least 18 inches in length, and often longer, will rest on the left side of the ab-

domen, crossing from the region of the ligament of Treitz down to the left of the midline and ascending again for the anastomosis to the esophagus and then descending laterally for the anastomosis of the distal to the proximal loop of jejunum.

Following this last lateral anastomosis, the operation will have been completed except for careful inspection of the left hypochondrium to make sure there is no persistent ooze from the nonperitonealized area of the posterior abdominal wall where the partly intraperitoneal spleen has been removed. As one views this area the tail of the pancreas, the left suprarenal gland and the top of the kidney, and the under surface of the diaphragm will be plainly seen, and if there is any oozing it can be carefully controlled. The left lobe of the liver is permitted to fall back in its position. We have never found it necessary to resuture it to the diaphragm.

There have been reports to the effect that following this operation there have been accumulations beneath the left diaphragm which have required drainage and on laboratory examination have proved to be made up at least in part of pancreatic secretion. We have not been bothered by this and we believe that, if one is careful to ligate the individual splenic vessels under direct vision, and if they are clearly separated from the tail of the pancreas, this will not occur. We believe, in addition, that careful and painstaking control of all oozing vessels in the left hypochondrium will also obviate this difficulty. We do not mean to say that we have not had any cases of subphrenic accumulations, but they have occurred in only a limited number of cases. Accumulations of pancreatic discharges beneath the diaphragm on the left side have not been one of our problems.

Since many patients undergoing total gastrectomy for carcinoma will be in a far from satisfactory state, I have lately leaned toward closure of the wounds with wire. The fact remains, however, that in many of our cases catgut and silk have been used. While I have no fixed convictions on the subject, I am inclined to favor the use of wire, under certain indications, in the belief that it will reduce the number of instances of wound disruption.

POSTOPERATIVE CARE

One should not leave the discussion of the technic of total gastrectomy without at least mentioning how necessary it is for these patients, after operation, to be in the hands of especially trained men—in our group in the hands of the gastroenterologists who are particularly interested and experienced in the selection of their food and in determining the

number of meals they should have and when their feedings can be changed from five or six per day to a more limited number.

The problems which may arise after total gastrectomy fall into three main classifications.

1. *Dysphagia* Many patients experience some temporary difficulty in swallowing, apparently owing to the fact that the small intestine is unaccustomed to receiving food directly from the esophagus. These patients experience regurgitation of food and mucus from the esophagus and some patients have the typical symptoms of the dumping syndrome consisting of sweating, weakness, palpitation and nausea. These symptoms are usually temporary and are best treated by giving frequent feedings of small quantities of well-chewed or puréed food. When the dumping syndrome symptoms are prominent, the more solid foods are often better tolerated than liquid food.

2. *Nutrition*. Practically all patients following a total gastrectomy experience some difficulty in maintaining weight. Very few of them regain their normal preoperative weight. However, their nutrition can be kept satisfactory if they eat frequently and train themselves to take larger quantities of food. Usually there is not much difficulty with the appetite but they are quickly satisfied by eating.

3. *Hemopoiesis*. Since the antipernicious anemia factor is apparently elaborated in other parts of the gastrointestinal tract than the stomach, not all patients with total gastrectomy develop pernicious anemia. However, pernicious anemia-like blood states have been observed in some cases and it is probably advisable to give some liver extract to all patients after a total gastrectomy. An injection of 15 U.S.P. units every two to four weeks and frequent check-up blood counts and hemoglobin estimations are advisable. It is well also to administer 5 mg. of folic acid twice a day in these cases.

None of these patients should be permitted to detach themselves from a medical adviser until it has been determined how well they will be able to manage their food, how well their blood pictures can be maintained on routine feedings, and how well they regain their activity and strength. Several of our patients have developed secondary anemia. When patients have called by telephone to say that they cannot get their breath after going up and down stairs, we have concluded, and usually correctly, that they have secondary anemia of such degree as to result in an insufficient number of red cells for carrying an adequate amount of oxygen.

It is true that many of these patients do not regain weight but it is likewise true that as these patients go on beyond their first year they become better and better able to handle food, they tend to regain their ability to gain some weight, and do regain practically all of their strength.

CONCLUSIONS

Total gastrectomy is no longer the forbidding operation it used to be. Its mortality has been brought down to within limits nearly as reasonable, if not just as reasonable, as those of subtotal gastrectomy. As an approach to the problem of the surgical treatment of gastric malignancy, it is a much more logical and reasonable method than is subtotal gastrectomy. While enough comparable figures are not available, it seems reasonable to assume that if this operation were more often applied than subtotal gastrectomy, the present depressing low five-year non-recurrence rate for the surgical treatment of carcinoma of the stomach could be improved.

PARTIAL GASTRIC RESECTION FOR PEPTIC ULCER

SAMUEL F. MARSHALL

Partial gastrectomy is still a most important surgical method for treatment of peptic ulcer, whether duodenal, gastric or jejunal, and at the Lahey Clinic we continue to place most of our reliance for permanent effective treatment of ulcer on resection of the stomach. With the advent of vagotomy we had hoped that many of the difficulties of resection, both technically and postoperatively, could be avoided. As Wilkinson has pointed out, with vagotomy the stomach could be left intact, a large percentage (88) of ulcer patients could be relieved of pain, and anacidity or low acid values could be obtained in a fairly large group of cases, but this decrease in gastric acid could not always be attained nor was the resultant anacidity permanent in many cases. At the Lahey Clinic vagotomy has been carried out in over 90 cases. In a recent review of 62 patients with vagotomy, it was evident that these patients had more postoperative difficulty, more severe and more persistent symptoms and just as many recurrent ulcers as a similar group of patients who had partial gastric resection only. The problem of vagotomy is by no means settled but the complications and dangers should be recognized as well as the benefits to be obtained from this lesser technical procedure as opposed to the more radical operation of partial resection.

FACTORS ESSENTIAL FOR GOOD RESULTS

Partial gastrectomy can be done with a large margin of safety and with excellent results in the majority of cases but any good postoperative results depend upon a number of factors.

First, the results depend upon the proper selection of patients to be submitted to surgical treatment. The indications for surgical treatment have been restated many times and are clear: perforation, repeated massive hemorrhages, obstruction and failure to relieve symptoms by adequate medical treatment, demand surgical interference. Gastric ulcers which fail to heal under medical treatment, or recur after healing, likewise demand resection. It is our feeling that vagotomy should almost never be used for gastric ulcer, since surgical interference is advised because of the uncertainty of the ulcer being benign or malignant. In a previous study of the problem of gastric ulcer, we found 26 malignant ulcers among 131 gastric ulcers, an incidence of 19.6 per cent; these patients were submitted to surgery because of failure of the ulcer to heal or because of recurrence of gastric ulcer after healing under medical treatment.

Second, good results after resection depend upon adequate resection; two-thirds or three-fourths of the stomach must be removed to prevent recurrent ulcer. Removal of the pylorus or antral area of the stomach carries as much surgical risk as a high resection and will result in recurrent ulcer in a large percentage of cases.

Third, operation, whether partial resection or gastroenterostomy, does not permit the patient to eat everything and to avoid long-continued *postoperative ulcer management*. He should follow a careful dietary regimen and be under the care of his gastroenterologist for a long period of time to avoid recurrent ulcer.

Lastly, meticulous attention to technical details of the operation, avoidance of contamination from visceral contents during operation, control of hemorrhages and avoidance of trauma will make for lower mortality and will contribute greatly to an uneventful, uncomplicated *postoperative recovery*.

The type of technical procedure employed in partial resection of the stomach makes no great difference if sufficient stomach is removed and if the ulcer is also removed, which can be done in almost every case if the relationship of the ulcer, especially duodenal ulcer, to important structures such as the common bile duct is recognized. Resections which do not include removal of the ulcer are palliative resections and are not true radical partial resections and should not be termed so. This type of palliative resection may result in a high percentage of recurrent ulcers. The Finsterer resection with exclusion of the ulcer is such an operation and has not been used in this clinic for seven or eight years. In an early series of cases in which the Finsterer procedure was occasionally employed, ulceration recurred in over 50 per cent. In several instances in which a jejunal ulcer recurred after a high resection but with the duodenal ulcer not removed, we were able to effect healing of the recurrent ulcer by simply excising the unremoved antral part of the stomach.

MODIFIED HOFFMEISTER TECHNIC

The method of resection of the stomach routinely employed in the clinic for the past ten years has been a modification of the Hoffmeister technic of partial gastric resection. The gastrojejunal anastomosis is made anterior to the transverse colon with the proximal loop of jejunum placed at the greater curvature of the stomach. As stated previously, a radical resection of the stomach is uniformly employed with removal of two-thirds or three-fourths of the stomach. It is our opinion that recurrence of ulcer with few exceptions is related to a large degree to insufficient removal of the stomach.

A left paramedian or transrectus incision is made, extending from the

left costal margin to the level of or below the umbilicus; the incision is made long enough to permit adequate exposure of the stomach and duodenum. The incision on the left side of the abdomen is preferred since the pylorus normally lies in the mid line of the abdominal cavity and the duodenum is only slightly to the right. This incision allows ready approach to the fundus and even the cardia of the stomach and thus permits a high resection to be carried out easily under the left costal margin. The muscles, fascia and other layers of the incision in the abdominal wall are protected by abdominal pads containing a layer of waterproof cellophane between the gauze to prevent contamination of the incision when the lumen of the stomach or jejunum is opened into during the operation.

After exploration of the abdominal viscera, the location of the ulcer is identified and its relation to other structures is determined. Should the ulcer be located in the *duodenum*, its relationship to the common bile duct and ampulla of Vater must be established before attempting to mobilize the duodenum and pylorus in preparation for resection. In chronic, deeply penetrating duodenal ulcers, in which there is much inflammatory reaction about the ulcer, a layer of scar tissue envelops the first and second portions of the duodenum which will conceal the outline of the duodenum. The convexity of the duodenum is mobilized by division of this scar tissue and peritoneum parallel to the upper border of the duodenum, the course of the duodenum and its relation to the gastrohepatic ligament are easily delineated and the duodenum may be turned medially. If the ulcer is low in the duodenum or adherent to the gastrohepatic ligament, the common bile duct must be exposed and visualized (Fig. 285). The common bile duct is then incised longitudinally, and the ampulla of Vater is dilated by the Bakes dilators in order that a limb of a rubber T-tube can then be passed into the duodenum. This placing of the T-tube into the bile duct and through the ampulla of Vater into the duodenum establishes definitely the course of the bile duct and its relation to the ulcer. The ulcer may then be removed without danger of injury to the common bile duct. This is a simple but extremely important maneuver in preventing injuries to the bile duct with their resultant stricture formation and postoperative obstruction to the flow of bile into the duodenum. Intubation of the common bile duct does not increase postoperative morbidity or adversely affect mortality but, on the contrary, greatly facilitates mobilization of the duodenum and removal of the ulcer in difficult cases. However, it is well to emphasize that exposure and intubation of the common bile duct are necessary in only a few cases, that is, those in which the ulcer is low in the duodenum or induration and inflammation about the ulcer involves the structures about the common duct.

When it is definitely established that a duodenal ulcer can be removed without injury to these important adjacent structures, the greater and lesser curvatures of the stomach are mobilized by clamping, section and ligation of the blood supply in the gastrocolic and gastrohepatic omentum (Fig 286). If the patient is obese or the omentum is thickened with fat, it is detached from the colon and resected with the stomach. This makes the resection much easier and permits an easier exposure and direct ligation of large vessels around the pylorus; it also permits an anterior gastrojejunostomy to be made more easily. Mobilization of the pyloric area and duodenum can be facilitated by passing a sponge poste-

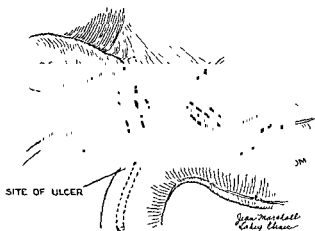


Fig 285 —Pyloric end of stomach and first part of duodenum. The ulcer is adherent to the gastrohepatic ligament and common bile duct. The common bile duct has been exposed, incised longitudinally and a rubber T-tube inserted with the long limb passed through the ampulla of Vater into the duodenum. This will aid materially in establishing the location of the ampulla of Vater and permit easier dissection of the duodenum and ulcer from the common bile duct and pancreas.

rior to the stomach and using this as a traction tape to elevate the stomach. Following mobilization of the pylorus and duodenum, the duodenum is divided and the distal divided end closed by one of several methods (Fig. 287). The mobilization of the lower end of the stomach and the duodenum is made readily if one recalls that the gastrocolic omentum and mesocolon are fused just below the antrum of the stomach. This area of fusion consists of avascular areolar tissue which separates easily if the peritoneum over the pancreas is divided at the point of reflection onto the posterior wall of the stomach (Fig 288), permitting the mesocolon with its middle colic vessels to be brushed down gently with gauze. This will expose the gastroduodenal artery as it courses over the head of the pancreas posterior to the antrum of the stomach.

This artery can be divided and ligated at the inferior border of the pancreas. The chronic indurated ulcer which is usually on the posterior wall of the duodenum may be adherent to the pancreas and usually such an ulcer has penetrated the wall of the duodenum so that the ulcer base

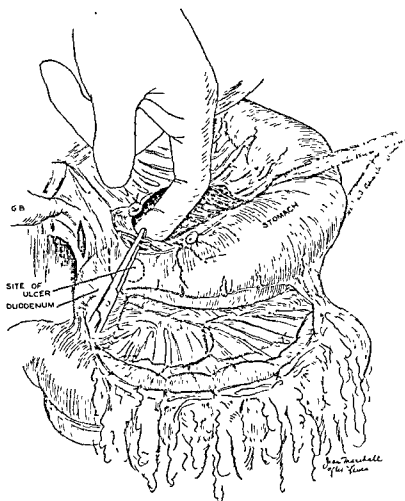


Fig 286—Mobilization of the stomach and duodenum. The gastrocolic and gastrohepatic omenta have been divided and ligated. The right gastric vessels are shown along the superior border of the duodenum. Note the relation of the common bile duct to the duodenum and ulcer. The gauze sponge is passed around the stomach and used to elevate the stomach

consists of pancreatic and scar tissue. It is not necessary to remove this base; the ulcer is removed by detaching the ulcer orifice on the duodenal wall from its ulcer base.

With the duodenum divided and the distal end closed, the stomach is drawn upward and to the left of the abdomen (Fig. 289). If the resection is done for *gastric* ulcer, the ulcer is often found attached to the pancreas or liver. This adherent indurated ulcer can be detached easily

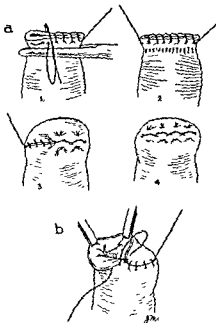


Fig. 287 --Closure of the duodenum, several methods may be used as shown in *a* and *b*
a, The duodenal stump may be sutured with a running stitch of chromic 0 catgut (1) and the clamp removed (2) The closed duodenal end is then inverted with interrupted mattress sutures of black silk (3, 4)

b, When the duodenal stump after mobilization and removal of the ulcer is short, no clamp is applied in order that duodenal length may be conserved, a Connell stitch of chromic 0 catgut is used to invert the open end of the duodenum, this is then reinforced with interrupted mattress sutures of black silk. This in turn may be further reinforced by suturing the closed end of the duodenum against the scarred head of the pancreas

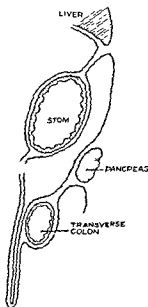


Fig. 288.--The layers of the peritoneum are shown in relation to the omentum, stomach and lesser peritoneal cavity. Recognition of the anatomy of these peritoneal layers permits easier mobilization of the pyloric part of the stomach and duodenum.

under direct vision by sharp or blunt dissection. The left gastric artery is visualized and divided at a high level along the lesser curvature of the stomach. The lesser curvature of the stomach is cleaned of omental tissue and this is likewise done on the greater curvature, ligating one or

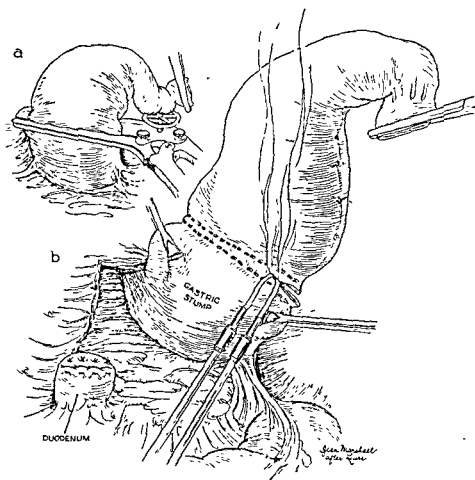


Fig 289 —The duodenum has been divided and closed by inversion. The stomach is elevated and drawn to the left.

a, The von Petz clamp has been applied at the level at which the stomach is to be divided, leaving about one-third or one-fourth of the stomach above the clamp.

b, The stomach is now divided between the double row of inserted clips with the cautery. Note that the borders of the stomach above the clips have been cleaned of omental tissue to permit more accurate inversion of corners and more accurate anastomosis of jejunum to stomach.

two of the short gastric vessels. This clearing of the borders of the stomach will permit accurate approximation and inversion of the gastric wall at the borders of the stomach (Fig. 289); about two-thirds or three-fourths of the stomach is removed. Before dividing and removing this portion of the stomach, however, the loop of jejunum which is to form the gastrojejunal anastomosis close to the ligament of Treitz is brought

anterior to the colon. This will prevent unnecessary contamination at the time of division of the stomach, so that the protecting abdominal pads do not have to be disarranged to select the proper loop of jejunum.

The von Petz clamp is now applied at right angles to the long axis of

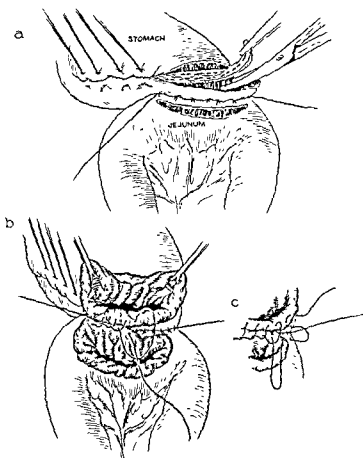


Fig. 200.—The lesser curvature end of the transected stomach is inverted with clips in place with a continuous chromic 0 catgut suture which is then reinforced with interrupted mattress sutures of black silk (see a). The jejunum is sutured to the posterior wall of the stomach at the site of anastomosis with interrupted sutures of black silk. The jejunal lumen is opened into by longitudinal incision and the stomach is opened by cutting away the clips in the uninverted end of the stomach. This will form the gastrojejunal stoma. A second posterior continuous interlocking stitch of chromic catgut is then placed and this is continued anteriorly as a Connell stitch (b and c) to close the anastomosis and form the stomal orifice.

the stomach at the level at which the stomach is to be divided and the clips are inserted (Fig. 289). A Payr clamp is applied just distal to the double row of clips and the von Petz clamp is removed. A Babcock clamp is applied at the level of the clips on the lesser and greater curvature to

support and elevate the gastric stump when the stomach is divided by cautery between the two rows of clips.

The upper one-half or two-thirds of the transected end of the stomach with the clips in place is inverted with a continuous suture of No. 0 chromic catgut on an atraumatic needle (Fig. 290). This suture line is reinforced with a second layer of interrupted mattress sutures of silk. The lower uninverted end of the stomach along the greater curvature will form the gastric stoma into the jejunum.

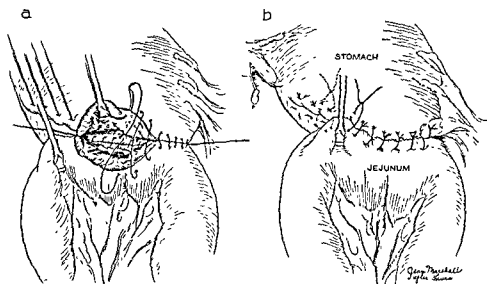


Fig. 291.—Completion of the gastrojejunal anastomosis which completes the partial resection of the stomach. *a*, Note that the chromic catgut stitch which forms the second posterior suture layer is continued anteriorly as a Connell suture which closes the lumen of the stomach and of the jejunum to form the gastrojejunal stoma.

b, The completed anastomosis which is reinforced with interrupted sutures of black silk. Note that the jejunum beyond the anastomosis is sutured to the closed and inverted end of the stomach. Note also that, for reinforcement, the gastrocolic omentum is sutured in the angle formed by the stomach and jejunum at the greater curvature of the stomach.

The selected loop of jejunum is brought anterior to the transverse colon and is sutured to this uninverted end of the stomach with interrupted mattress sutures of silk. The gastrojejunal stomal orifice should be about three fingerbreadths in width.

The jejunum is opened by a longitudinal incision and the uninverted end of the stomach is opened by excising the crushed portion with its clips (Fig. 290). Contamination is prevented by suction of jejunal and gastric contents. All active bleeding points are ligated by fine catgut. A second posterior suture of chromic catgut is begun at the right end of the anastomosis and carried as an interlocking stitch through all layers of the jejunum and gastric wall toward the greater curvature of the stomach. This posterior interlocking suture of catgut is then continued

anteriorly from the greater curvature end to the right as a Connell stitch, serving to invert the gastric and jejunal edges and thus closing the anastomosis and forming the gastrojejunal stoma. This anterior suture line is reinforced with interrupted (Lempert) sutures of silk.

The distal jejunal loop beyond the stomal area toward the lesser curvature is buttressed against the closed inverted end of the transected stomach to reinforce the suture line and to remove tension on angle sutures of the anastomosis (Fig. 291). The gastrojejunal angle at the greater curvature is reinforced by suturing the divided end of the gastrocolic omentum to this angle. The proximal jejunal loop is thus placed at the greater curvature.

Entero-enterostomy between the proximal and distal jejunal loops should not be done. This not only is unnecessary for proper drainage of stomach but deflects the alkaline duodenal contents from the stomal

TABLE 1

PARTIAL GASTRIC RESECTION FOR PEPTIC ULCER 1937-1948 INCLUSIVE

	Number of Patients	Number of Postoperative Deaths	Operative Mortality, Per cent
Duodenal ulcer	710	16	2.53
Gastric ulcer	205	3	1.46
Jejunal ulcer	133	3	2.3
Gastrojejuno-colic fistula	31	2	6.5
Total operated cases	1079	26	2.4

orifice. This is an important factor in preventing recurrent ulcer at the gastrojejunal anastomosis. The abdominal cavity is inspected for bleeding points before closing the abdominal wound, which is done without drainage.

The abdominal wound is closed in layers of the peritoneum, fascia, muscle and skin, the peritoneum is closed with a continuous suture of chromic catgut. By use of the waterproof cellophane pads, any contamination of the abdominal wall incision is prevented. We are, therefore, able to employ interrupted silk sutures in approximating muscle, fascia, subcutaneous tissue and skin. This is also a layer closure. Should the patient be elderly or have poor abdominal wall tissues, further reinforcement of the incision may be obtained with a few interrupted retention sutures of heavy silk. These latter stitches are rarely necessary and the large percentage of these wounds heal without infection, and rarely is disruption of wound observed. The operative mortality

following partial gastric resection for peptic ulcer for the past 12 years has been 2.4 per cent in 1079 cases (Table 1).

Partial gastrectomy can be done with low mortality even with many patients who have serious complicated ulcers. Postoperative results following partial gastrectomy are, in general, excellent.

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PARTIAL PANCREATECTOMY: EXCISION OF THE TAIL AND BODY OF THE PANCREAS

RICHARD B. CATTELL

Considerable progress has been made in recent years in the surgical treatment of diseases of the pancreas. With increased interest and study of this problem, more conditions have been successfully treated by partial or total removal of this gland. Unfortunately, there are serious obstacles to the establishment of a correct diagnosis both before operation and at the time of abdominal exploration. With an increasing experience in the management of these lesions it is probable that means will be discovered which will permit more accurate diagnoses. It is only by keeping in mind the possibility of the presence of the lesions of the pancreas in obscure upper abdominal conditions that the presence of the pancreatic lesions may be suspected or proved. Unfortunately, there are few diagnostic aids, such as the roentgenographic visualization of organs adjacent to the pancreas, when distortion or displacement of these organs occurs. Determinations are made of the amylase or lipase concentration in the blood and incomplete digestion of carbohydrates and protein may be found by special studies of the stools. At times lesions of the pancreas attain sufficient size to produce localizing signs in this region. For the most part, however, it is necessary to make a presumptive diagnosis of a pancreatic lesion based on the history in the absence of other demonstrable findings.

There has been sufficient experience in the surgical treatment of pancreatic lesions to demonstrate that this organ is amenable to surgical attack. When the lesion involving the pancreas is sufficiently serious to justify a major procedure it must be appreciated that it carries considerable risk both as to morbidity and mortality. In the Surgical Clinics of North America for June 1948, I presented the technic employed in this clinic for removal of malignant lesions involving the lower end of the common bile duct, ampulla of Vater, duodenum and head of the pancreas. This procedure of radical pancreatoduodenal resection has been carried out for 63 malignant lesions and 5 benign lesions in this area, with mortality of approximately 13 per cent. We have encountered fewer lesions that are confined to the tail or body which are amenable to surgical removal. In the past three years, partial pancreatectomy with removal of the tail and body of the pancreas has been carried out a number of times without mortality. The technic of this operation will be presented.

INDICATIONS FOR OPERATION

1. Cysts of the Pancreas
2. Recurrent Relapsing Pancreatitis
3. Pancreatolithiasis
4. Pancreatic Fistulas
5. Islet Adenoma
6. Carcinoma of the Body of the Pancreas

The single cysts encountered in the body of the pancreas that do not communicate with the ducts can usually be excised without removal of portions of the pancreas. When they are of large size and associated with chronic inflammation, operation may be conducted in two stages with marsupialization and drainage of the cyst at the first stage, followed by removal of the tail and body in three months, during which time the cavity shrinks to a small size, permitting more accurate identification of the surrounding structures. Most of the single cysts that communicate with the ducts are best treated either in one or two stages by partial pancreatectomy. The multilocular cysts which usually follow recurrent inflammation of the gland may be treated in a similar manner, but all require resection of the body to accomplish complete relief of symptoms. We have not encountered multiple or multilocular cysts that appear to be of congenital type.

Increasing numbers of patients are being seen with chronic relapsing pancreatitis. If the process is chiefly confined to the body, partial pancreatectomy offers the best chance of relief of the disabling pain and digestive symptoms. This lesion is likely to be extensive and in some cases, after exploration, partial pancreatectomy has been deemed unwise and an attempt made to relieve the symptoms by left thoracolumbar sympathectomy.

Pancreatolithiasis is infrequently encountered. We have observed cases with the stones confined to the head, and 2 cases with pancreatolithiasis and diffuse calcinosis limited to the body and tail. The severe symptoms present in these cases justify partial pancreatectomy when technically feasible. It has been carried out in 2 patients.

Pancreatic fistula may be the result of trauma or penetrating wounds or may follow acute pancreatitis when drainage has been instituted. Pancreatic fistula, however, most frequently occurs as a result of drainage of cysts of the pancreas. At times, these fistulas may be transplanted into the jejunum or stomach. Excision of the fistula with closure of the communications to the pancreatic ducts is rarely successful. Partial pancreatectomy may be the most effective means of curing this condition. Failure to discover hyperfunctioning pancreatic adenomas of the islet cells may necessitate partial pancreatectomy, as suggested by

Waugh, when the adenoma cannot be discovered. In the few patients treated at the clinic the adenoma has been found and removed locally but in 1 case in which the adenoma showed malignant degeneration, partial pancreatectomy was carried out by Marshall.

We have had no experience with partial pancreatectomy for carcinoma of the body of the pancreas. A successful case was reported by Gordon-Taylor in 1934; the patient was living at that time, seven years after partial pancreatectomy. Unfortunately, most of the malignant lesions of the body of the pancreas already have extended beyond the gland, making resection impossible.

ANATOMY

The most satisfactory approach for exposure of the body and tail of the pancreas is through the gastrocolic omentum on the left side. The tail of the pancreas is usually in close relationship to the lower portion of the hilum of the spleen and injury to the latter structure may be unavoidable, particularly if chronic inflammation of the pancreas is present. The upper portion of the transverse mesocolon may likewise be densely adherent to the inferior border of the pancreas, making a line of dissection difficult to obtain. The stomach is usually adherent to the anterior surface of the pancreas, but can usually be disengaged without difficulty.

The protection of the vascular structures in the region of the pancreas is the most difficult technical part of the operation. These structures are by no means constant in their course and relationship and must be individually identified as the procedure is carried out. The splenic artery passes along the superior aspect of the body, giving off branches to both the body and tail. There are large longitudinal arteries from the gastroduodenal artery that pass into the pancreas on its superior aspect. Similarly, the inferior pancreatoduodenal artery gives large branches to the body on the inferior surface. Both the middle colic arteries and the inferior mesenteric artery must be carefully identified and displaced downward to avoid injury.

The large venous channels in this area are even more difficult to identify and protect than the arteries. The splenic vein lies on the superior aspect of the body and, as it passes to the left, comes to rest behind the body and tail. When inflammation is present it may appear to be an integral part of the pancreas. The junction of the splenic and superior mesenteric veins forms the portal vein and must be identified previous to division of the neck of the pancreas.

In partial pancreatectomy only the duct of Wirsung is encountered. The accessory duct rarely passes beyond the neck of the pancreas. If some degree of obstruction to the duct is present it can usually be identified by palpation on the anterior surface or by aspiration.

INDICATIONS FOR OPERATION

1. Cysts of the Pancreas
2. Recurrent Relapsing Pancreatitis
3. Pancreatolithiasis
4. Pancreatic Fistulas
5. Islet Adenoma
6. Carcinoma of the Body of the Pancreas

The single cysts encountered in the body of the pancreas that do not communicate with the ducts can usually be excised without removal of portions of the pancreas. When they are of large size and associated with chronic inflammation, operation may be conducted in two stages with marsupialization and drainage of the cyst at the first stage, followed by removal of the tail and body in three months, during which time the cavity shrinks to a small size, permitting more accurate identification of the surrounding structures. Most of the single cysts that communicate with the ducts are best treated either in one or two stages by partial pancreatectomy. The multilocular cysts which usually follow recurrent inflammation of the gland may be treated in a similar manner, but all require resection of the body to accomplish complete relief of symptoms. We have not encountered multiple or multilocular cysts that appear to be of congenital type.

Increasing numbers of patients are being seen with chronic relapsing pancreatitis. If the process is chiefly confined to the body, partial pancreatectomy offers the best chance of relief of the disabling pain and digestive symptoms. This lesion is likely to be extensive and in some cases, after exploration, partial pancreatectomy has been deemed unwise and an attempt made to relieve the symptoms by left thoracolumbar sympathectomy.

Pancreatolithiasis is infrequently encountered. We have observed cases with the stones confined to the head, and 2 cases with pancreatolithiasis and diffuse calcinosis limited to the body and tail. The severe symptoms present in these cases justify partial pancreatectomy when technically feasible. It has been carried out in 2 patients.

Pancreatic fistula may be the result of trauma or penetrating wounds or may follow acute pancreatitis when drainage has been instituted. Pancreatic fistula, however, most frequently occurs as a result of drainage of cysts of the pancreas. At times, these fistulas may be transplanted into the jejunum or stomach. Excision of the fistula with closure of the communications to the pancreatic ducts is rarely successful. Partial pancreatectomy may be the most effective means of curing this condition. Failure to discover hyperfunctioning pancreatic adenomas of the islet cells may necessitate partial pancreatectomy, as suggested by

colon downward. Elevation of the stomach and depression of the posterior layers of the transverse mesocolon permit wide exposure and access to the body and tail of the pancreas (Fig. 292).

Most of the lesions involving the body and tail for which partial pancreatectomy is necessary lead to such gross changes in the pancreas and adjacent structures that the limits of the pancreas are hard to determine. For this reason, removal of the spleen, leaving it attached to the

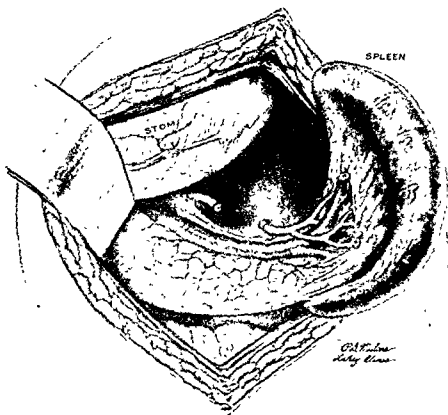


Fig 293.—The splenic artery has been ligated and divided, as well as the vasa brevia. The spleen has been delivered from the wound and the tail of the pancreas is elevated.

pancreas, is necessary. The splenic artery is first identified as it comes down from the celiac axis (Fig. 292). It is ligated and divided at the point where it passes to the left at a considerable distance from the spleen (Fig. 293). After division of the vasa brevia vessels to the upper portion of the spleen, the latter is delivered from the wound with elevation of the tail of the pancreas (Fig. 293).

Dissection is then carried out from in back, elevating the spleen and tail of the pancreas from the kidney and identifying the structures of the hilum of the kidney. Great care must be directed to protect the inferior mesenteric artery and vein, which are in contact with the inferior margin

of the body of the pancreas, separated only by the one posterior layer of the peritoneum of the transverse mesocolon. With further elevation of the body of the pancreas, the splenic vein is isolated and separated from the superior aspect of the pancreas. Displacement of this structure backward permits its accurate ligation and division. The proximal side of the splenic vein is then followed to its junction with the superior mesenteric

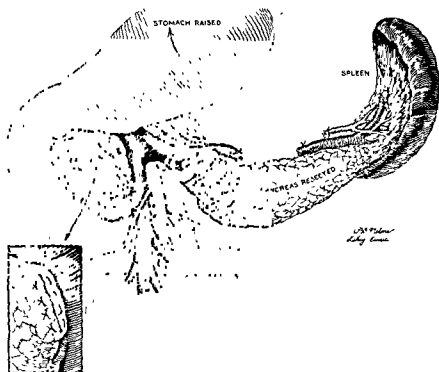


Fig 294—Diagrammatic representation of the major structures encountered at the junction of the body and head of the pancreas. The splenic vein has been ligated (as have the branches from the gastroduodenal and superior mesenteric arteries). The neck of the pancreas has been divided showing the duct of Wirsung.

Inset, Closure of the cut end of the pancreas.

vein. At times this dissection must be discontinued because of technical difficulties, and the neck of the pancreas is elevated after identification of the superior mesenteric vein and portal vein. The longitudinal superior pancreatic arteries, both anterior and posterior, as they leave the gastroduodenal artery are now secured and ligated. Following this, the short arterial branches of the superior mesenteric artery at the inferior border of the pancreas are dealt with. If the neck of the pancreas has not already been divided, it is divided at this time, with removal of the operative specimen (Fig. 294). As the neck of the pancreas is sectioned, the duct

of Wirsung is identified and carefully closed by nonabsorbable suture ligatures. The neck of the pancreas is then carefully closed by interrupted nonabsorbable sutures, as shown in Figure 294, inset. This results in good hemostasis of the cut end of the pancreas, as well as effective closure of the tiny duct radicals.

Gelfoam is quite useful in the control of ooze from the bed of the pancreas. A small incision is then made through the gastrohepatic omentum for the introduction of a cigaret gauze drain to the bed of the pancreas. The gastrocolic omentum is then closed.

SUMMARY

An increasing number of lesions of the pancreas are being encountered which involve the body and tail.

Indications for partial pancreatectomy with excision of the tail and body of the pancreas are: cysts, recurrent cysts, chronic relapsing pancreatitis, pancreatolithiasis, pancreatic fistulas, islet adenoma and carcinoma. Inflammatory lesions are the most common.

A technic for partial pancreatectomy is presented.

of the body of the pancreas, separated only by the one posterior layer of the peritoneum of the transverse mesocolon. With further elevation of the body of the pancreas, the splenic vein is isolated and separated from the superior aspect of the pancreas. Displacement of this structure backward permits its accurate ligation and division. The proximal side of the splenic vein is then followed to its junction with the superior mesenteric

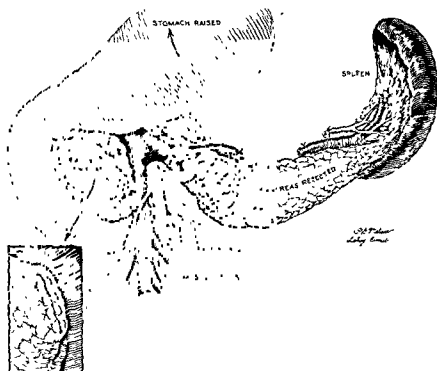


Fig. 294.—Diagrammatic representation of the major structures encountered at the junction of the body and head of the pancreas. The splenic vein has been ligated (as have the branches from the gastroduodenal and superior mesenteric arteries). The neck of the pancreas has been divided showing the duct of Wirsung.

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REPAIR OF INCISIONAL HERNIA

RICHARD B. CATTELL

Incisional or ventral hernia is a frequent late complication of abdominal surgery. It is usually the result of partial disruption of the fascial layer followed by an opening in the peritoneal layer. Unless actual eventration occurs it may not be recognized during the immediate postoperative period. It is usually the result of a wound complication such as bleeding or infection in the abdominal wall. If partial disruption can be recognized during the postoperative period by discharge of blood or serosanguinous fluid from the wound later hernia can usually be avoided if immediate secondary closure of the wound is accomplished. Incisional hernia most often occurs in obese individuals and is particularly prevalent when there has been a postoperative pulmonary complication. It is also common when abdominal surgery has been undertaken for malignant disease in debilitated and poorly nourished patients.

With better selection of the abdominal incision, the incidence can be decreased. The employment of transverse incisions and those which avoid cutting more than one or two nerves likewise will result in a stronger abdominal incisional scar.

The repair of large incisional hernias may be quite difficult by any type of procedure, particularly those with large defects of the abdominal wall. The use of nonabsorbable sutures in effecting the repair, and the use of fresh fascia as described by Gallie have given improved results. Alloy steel wire has been effectively utilized by Babcock and others to effect the repair. In large defects Koontz has described the use of large squares of tantalum mesh.

In 1942, I described a simplified technic for repair of large incisional hernias which was found quite practical. It has now been employed over a period of ten years with good results.

Patients who have large incisional hernias are frequently poor risks either because of obesity or because of cardiovascular or renal conditions. Because of the frequency of post-operative complications in this group of patients they should be very carefully studied previous to advising operation. Pulmonary complications and thrombophlebitis may follow repair but can usually be avoided. Obese patients should be put on a strict reduction diet and repair should be delayed whenever possible until their weight falls within a normal range. Because of the marked changes in intra-abdominal pressure produced by the repair, it is well during the period of preparation to have them fitted with an abdominal belt to

reduce the contents of the hernia as far as possible within the abdominal cavity.

In some patients, because of marked disability or abdominal pain, operation must be advised before weight reduction. Likewise, when incarceration is present with threatened or impending strangulation of the contents of the sac, operation must be carried out at a less advantageous time. With large hernias, at times the skin becomes ulcerated because of excessive pressure, and immediate operation should then be advised. Under these circumstances the technic which will be described is particularly applicable since it can be carried out with a minimum of technical difficulties even in very obese patients.

The usual technic employed for the repair of incisional hernia includes isolation of the sac and its contents, following which the layers of the abdominal wall are dissected out separately. This is frequently a long and tedious dissection and even when carried out in the best manner possible it may result in obtaining quite weak layers that are not easily sutured owing to their irregularity and weakness.

The chief difference in the conventional method of hernia repair and the plan which will be described is that the strong layer of the ring is not disturbed. This ring consists of fragments of the peritoneum, muscle and fascia and, in the upper abdomen, portions of the posterior rectus sheath and transversalis muscle. The layers of the abdominal wall are identified subsequently during the repair at some distance from the ring.

TECHNIC

After applying traction to the previous incisional scar, an elliptical incision is made around the scar incorporating the excess skin of the abdominal wall (Fig. 295, *a*). By firm traction, the contents of the sac will usually fall away. The incision is then continued outward through the layer of fat until the fascia is encountered (Fig. 295, *b*). These lateral flaps are freed up for a considerable distance laterally beyond the ring of defect, leaving a broad surface of fascia exposed. It is a relatively bloodless procedure. Traction is maintained on the sac and sharp dissection is carried out medially around the entire neck of the sac at its junction with the fascia (Fig. 295, *b*).

When a wide dissection of the flap has been carried out, the skin is incised over the sac, which is entered. The abdominal contents are completely freed from the sac and the dissection carried out well beneath the abdominal wall for the full circumference of the defect. It is frequently advisable to excise large portions of omentum. The skin is excised from the sac, and the fat cut away from its entire surface (Fig. 296, *a*). With the defect of the abdominal wall outlined, the peritoneum is approximated in a longitudinal direction with a continuous heavy

chromic interlocking suture, including all layers of the abdominal wall that are attached to the hernial ring (Fig. 296, *b*). This can be accomplished even when large defects are present.

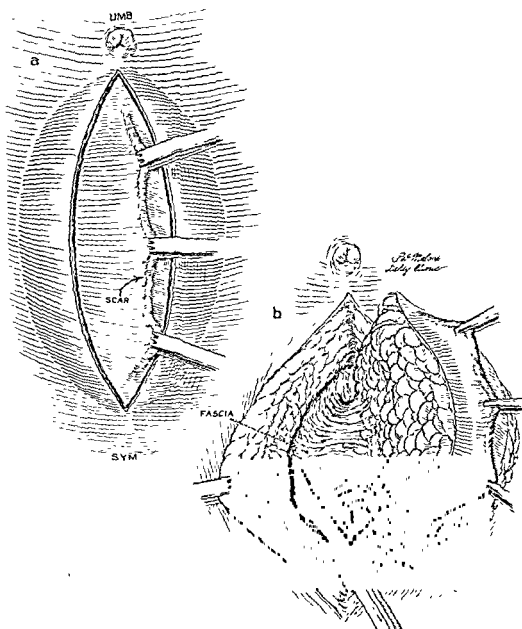


Fig 295.—*a*, The outline of the hernia is shown. An elliptical incision has been made enclosing the scar and excess skin.

b, Lateral flaps have been freed, exposing the fascia. The dissection is then carried medially to expose the edge of the defect in the abdominal wall.

The large redundancy of sac is cut away at a distance of 2 cm. from the previous suture line. This redundant portion of the sac, again con-

the abdomen if the previous incision has been made in the linea alba or midline. At times it is sufficient in lower midline incisions as well. It is

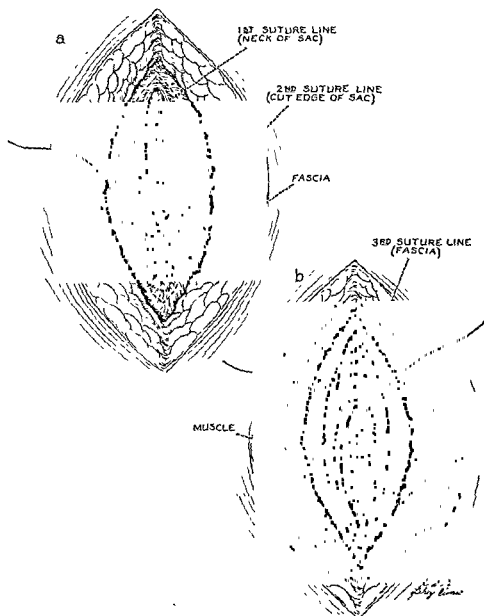


Fig 297.—*a*, The remaining free edge is sutured. The dotted line shows the position of the fascial incision.

b, The medial borders of the fascial layer are approximated. The muscle has been exposed.

recommended, however, that a further layer closure be effected, as will be described.

An elliptical incision is made at a distance of 2 cm. on each side lateral to the previous suture line in a position as indicated by the dotted line in

Figure 297, *a* This exposes the muscle on either side, which may be freed up to any extent desired. The medial borders of the elliptical incision are approximated as the third layer, as indicated in Figure 297, *b*.

The fascial layers are freed up for a considerable distance from the muscle and interrupted sutures are used to approximate the fascia at the upper and lower angles of the incision. This is done to take the tension off the muscle. Muscle sutures are then alternated with fascial sutures until the fourth and fifth layers are completed (Fig. 298). If the fascia approximates with too great tension, the lateral flaps of the incision, including skin and fat, are elevated and counterincisions in the fascia

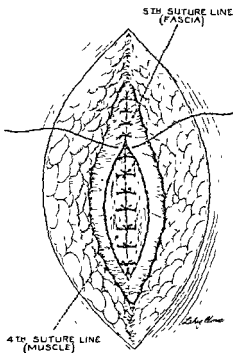


Fig. 298 — Alternating sutures are taken to approximate muscle and fascia

are made at some distance laterally. No attempt is made to close the lateral defect. Following the closure of the five layers, the fat and skin are separately sutured. Drainage of the wound is optional and is rarely used except to drain the fatty layer.

COMMENT

During the immediate postoperative period, full adhesive strapping to the abdomen is kept in place. Deep breathing exercises are encouraged, as is light coughing. With the abdominal support of a binder, early ambula-

tion is encouraged. We prefer to have the patients remain in bed for two days since all are operated on under pontocaine spinal anesthesia and headaches are avoided if ambulation is begun on the third day. Ace bandages are applied to the legs and leg exercises are carried out at frequent intervals during bed rest. Prophylactic use of dicumarol may be indicated. Patients are discharged from the hospital usually in ten to fourteen days, with a well-fitted canvas abdominal belt. Obese patients are given a low calorie diet and are advised to avoid gaining weight.

This plan for the repair of incisional hernia has been used in a large group of patients during the past ten years with very good results. The simplicity of the procedure, which can be carried out rapidly and without an involved dissection, possesses great advantages for the type of patient who has a large incisional hernia. The procedure is equally applicable to hernias located in the upper abdomen, both in the median line and through the vertical incision through the rectus muscle. It has been used more often in lower midline incisions and for low right rectus incisional hernias. The same principle has been employed in hernias of all sizes in all quadrants of the abdomen. In our experience, repair effected by this method is followed by a very low incidence of complications and recurrences.

SUMMARY

A technic for the repair of incisional hernia has been presented which is applicable to most incisional hernias irrespective of size. It has been carried out frequently in very obese patients when, because of complications, reduction of weight has been inadvisable.

The chief difference between this method of repair and the one generally employed is that the repair is carried out after dealing with the sac and its contents without separate dissection of the layers of the abdominal wall. The hernial ring is approximated, following which the layers are identified and approximated over this preliminary closure.

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THE REPAIR OF INGUINAL HERNIAS

KENNETH W. WARREN

The endless stream of medical literature describing methods of surgical repair of inguinal hernias reflects a disturbing lack of agreement regarding the fundamental anatomical and technical requirements for success in this field. Differences of opinion in assessing the relative importance of the various anatomical structures which constitute the abdominal wall in the inguinal region are central to this state of confusion. Ancillary sources of disagreement revolve around the choice of suture material, the utilization of continuous or interrupted sutures, the period of postoperative recumbency and the time of resumption of full physical activity.

INDIRECT VERSUS DIRECT INGUINAL HERNIA

In the literature of the past much attention was directed toward the differentiation of these separate types of hernias, from the standpoint of both clinical recognition and surgical repair. That the two types are dissimilar in location and origin cannot be seriously questioned. Nor can one substantiate the thesis that the anatomical requirements for adequate repair of these types of hernias are always the same, and yet one of the common errors in arriving at a reasonable concept of inguinal hernia repair is failure to recognize that an indirect hernia with a greatly widened internal ring (which widening always occurs at the expense of the transversalis fascia) is similar in its fundamental defect to a direct hernia.

It would be better, perhaps, for surgical considerations alone, to regard the small, indirect inguinal hernia in children and young adults in a separate class, for all that is required for their surgical elimination when the internal ring is not dilated is the complete excision of the sac with high ligation at its neck.

In large indirect hernias in which the transversalis fascia constituting the internal ring has been disrupted (and it may be disrupted all the way to the pubic spine by a progressively expanding indirect hernia) and in direct hernias, the primary concern in repair is the restoration of the integrity of the transversalis fascia. To the extent that the essential anatomical defects in indirect hernias with markedly enlarged internal rings and in direct hernias with disruption of the transversalis fascia in Hesselbach's triangle are the same, the surgical repair of each variety should be similar.

Many authors in recent years, particularly Bartlett, Zimmerman, Fallis, Anson and McVay, and Harkins, have stressed the significance of the transversalis fascia. Fallis has pointed out that in direct inguinal hernia the rectus muscles tend to be narrow in their inferior extent, that the external inguinal ring is congenitally enlarged and that the internal oblique and transversus abdominis muscles fail to become fibrous until they reach the lateral edge of the rectus sheath, thereby precluding the formation of any significant conjoined tendon.

Anson and McVay have been impressed during their anatomical and surgical dissections with the relationship of the transversalis fascia to the inguinal and to Cooper's ligament. They contend that the transversus aponeurosis does not attach itself to the inguinal ligament, but inserts into Cooper's ligament, and they have described a type of repair which approximates the medial aspect of the transversalis fascia to Cooper's ligament. Harkins has utilized this maneuver and attempts to justify its uniform application to all types of inguinal and femoral hernias.

THE REQUIREMENTS FOR INGUINAL HERNIA REPAIR

There are certain technical aspects of the surgical treatment of hernia, unrelated to controversial anatomical considerations, which may appear inconsequential, but which may prove decisive in the ultimate success or failure of any method of repair.

Anesthesia The muscular relaxation, the placid movements of the abdominal wall and the absence of intra-abdominal tension resulting from spinal anesthesia combine to make this the anesthetic method of choice in the repair of hernia.

Silk or similar nonabsorbable suture material is preferable to catgut. The employment of buried silk sutures presumes a high regard on the part of the surgeon for sharp dissection, careful hemostasis and the absence of undue tissue tension.

Early ambulation is safe and proper in most instances, but reducing the hospital stay materially below two weeks is a questionable practice.

Routine opening of the peritoneum at the internal ring in both direct and indirect inguinal hernia should be observed. This maneuver will accomplish several things. It will insure that an indirect sac will not be overlooked. It will permit an assessment from within the abdominal cavity of the status of Hesselbach's triangle and the femoral canal. It will obviate the greatest risk of injury to the bladder and it will permit the conversion of the direct sac, when present, to an indirect sac, after the manner of Huguot. The opening of the peritoneum, preferably at the internal abdominal ring, should be practiced in every repair of inguinal hernia.

Anatomical requirements for repair. If one accepts the thesis that the transversalis fascia constitutes the first restraining force the anterior abdominal wall offers to increased intra-abdominal tension, one must conclude that the restoration of the integrity of the transversalis fascia, in either direct or indirect hernias, is the *sine qua non* of an adequate repair. If this important structure is to be restored to its normal functional integrity it must be thoroughly exposed from the anterior pubic spine to the superior margin of the internal abdominal ring. This exposure is facilitated by the excision of the cremasteric muscles. It is important in indirect inguinal hernias with widening of the internal abdominal ring to detach the cremasteric muscle from the margins of the transversalis fascia at the internal ring in order that these margins may be approximated about the spermatic cord after the hernial sac has been eliminated. It is even more advantageous to remove the lower fibers of the cremasteric muscle when a direct defect is present so that the medial and lateral margins of the transversalis fascia in Hesselbach's triangle can be recognized and approximated without intervening cremasteric fibers. Bartlett has emphasized repeatedly the validity of this procedure in his writings on his concept of repair of inguinal hernia.

Reinforcing the transversalis fascia. In indirect hernia with minor degrees of disruption of the transversalis fascia at the internal ring, no elaborate means of reinforcement are required. Simple approximation of the freed margins of the transversalis fascia constituting the internal ring will suffice. The vulnerability of Hesselbach's triangle, on the other hand, is serious in direct inguinal hernias, and adequate surgical repair necessitates further reinforcement.

Innumerable approaches to this problem have been pursued, ranging from Bassini's approximation of the conjoined tendon to the shelving edge of the inguinal ligament, to recent attempts to utilize Cooper's ligament instead. The inadequacy of the former maneuver, in many instances, is related to the very limited extent or utter absence of a conjoined tendon and particularly to its unavailability except in the lowermost part of Hesselbach's triangle. More recently, Anson and McVay have questioned the reasonableness of utilizing the inguinal ligament for any part of the repair of inguinal hernias. They contend that the transversalis fascia does not insert into the inguinal ligament and they decried further the use of a mobile bastion, such as the inguinal ligament, on structural grounds.

Zimmerman, in a brief critique on the McVay concept, has pointed out (1) that the mobility of the inguinal ligament is not a serious objection to its utilization in inguinal hernia repair, since failures related to the mobilization of the inguinal ligament would appear as femoral recurrences, a type of recurrence rarely seen; (2) that the insertion of

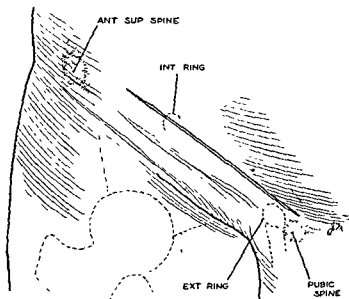


Fig 299 —Topography of right inguinal region showing skin incision approximately 2 cm above and parallel to the inguinal ligament, extending from the spine of the pubis to a point slightly below the anterior superior spine of the ilium.

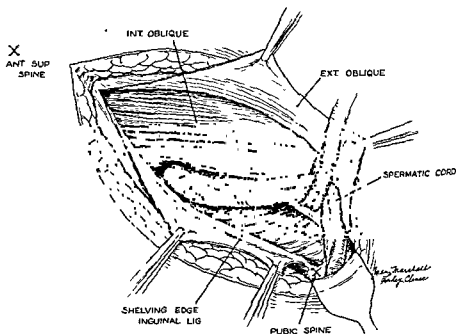


Fig 300 —The aponeurosis of the external oblique has been divided in the direction of its fibers. The lateral flap is reflected outward, revealing the shelving edge of the inguinal ligament. The spermatic cord is retracted medially, exposing the pubic spine.

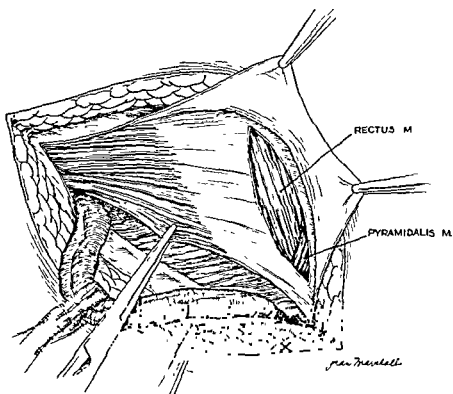


Fig 301.—The medial flap of the aponeurosis of the external oblique has been reflected medially, and the anterior rectus sheath has been incised vertically, near the midline, thereby relaxing the lateral margin of the rectus sheath

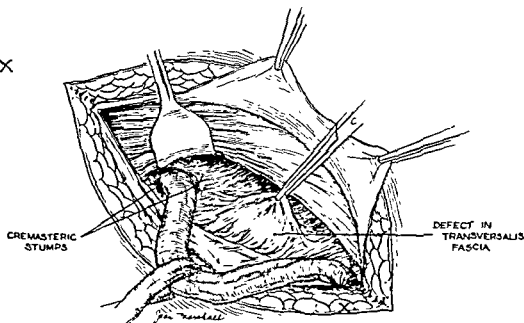


Fig 302.—The cremaster muscle has been removed, exposing thoroughly the direct defect in the transversalis fascia. The ligated stumps of the cremaster muscle are visible on the lateral and medial aspects of the internal abdominal ring

sutures into the anterior pubic ligament (Cooper) is difficult and hazardous in terms of possible injury to the femoral vein, and (3) that these sutures into Cooper's ligament cannot be carried far enough lateralward to protect the entire area of Hesselbach's triangle. Despite these objections, with which the present author agrees, excellent results have been reported with the utilization of this method of repair, and this means of

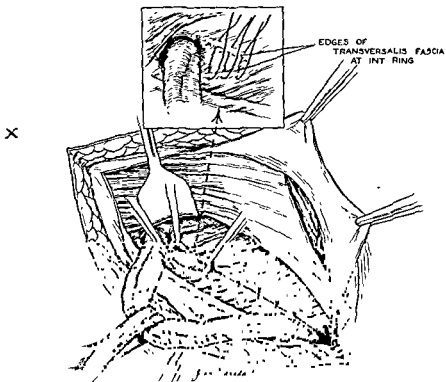


Fig 303 —The integrity of the transversalis fascia in Hesselbach's triangle has been restored by a series of interrupted silk sutures, invaginating the defective area shown in Figure 302. The conversion of the direct hernial sac into an indirect one is not shown in the illustration.

The insert shows the reconstruction of the internal abdominal ring by approximating the margins of the transversalis fascia snugly about the cord.

reinforcing the transversalis fascia at the lower level of the inguinal canal is occasionally employed.

The method of adding support to the floor of the inguinal canal upon which we generally depend comprehends the utilization of a relaxing incision in the internal oblique fascia near the midline where it constitutes part of the anterior rectus sheath, and approximation of the dense aponeurotic structure at the lateral margin of the rectus sheath to the shelving edge of the inguinal ligament.

In direct hernias and in indirect ruptures with disruption of the transversalis fascia, the floor of the inguinal canal is further reinforced by imbricating the aponeurosis of the external oblique beneath the mobilized cord structures after the manner of Halsted.

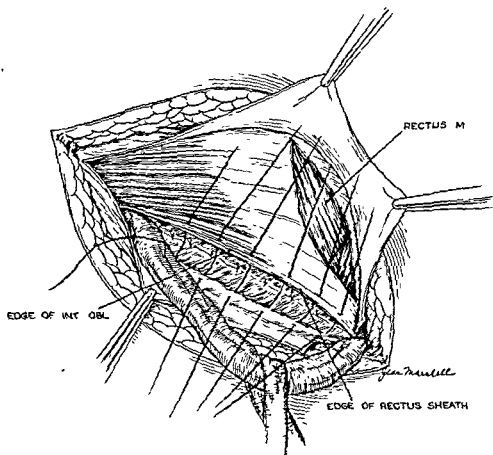


Fig 304 —The lower edge of the rectus sheath is being approximated to the shelving edge of the medial third of the inguinal ligament in order to reinforce the reconstructed transversalis fascia. Above this level the internal oblique muscle is sutured to the inguinal ligament. The advantage of the relaxing incision in the anterior rectus sheath will become evident as these sutures are tied.

TECHNIC

An incision is made in the skin and subcutaneous tissue about 2 cm. above and parallel to the inguinal ligament, extending from the level of the internal abdominal ring to or slightly beyond the spine of the pubis (Fig. 299). The segment of the spermatic cord between the external abdominal ring and the scrotal entrance is retracted medially, exposing the spine of the pubis. The aponeurosis of the external oblique muscle is incised and the lateral leaflet is mobilized to the depth of the shelving edge of the inguinal ligament (Fig. 300). The medial flap is

mobilized to the point of its insertion into the anterior rectus sheath near the midline. The relaxing incision in the anterior rectus sheath is made at this time (Fig. 301). The cord is mobilized from the inferior

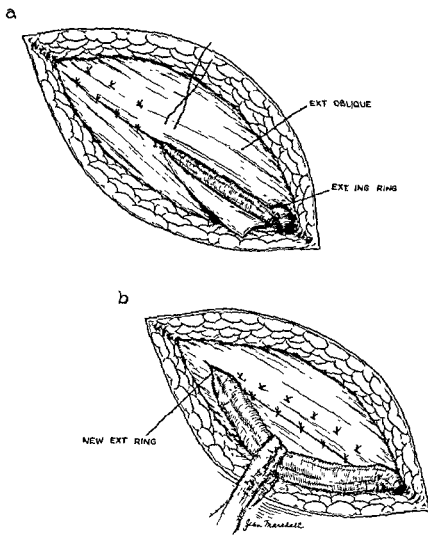


Fig 303 —a, The sponeurosia of the external oblique is being imbricated over the spermatic cord. This method of closure is preferable in small indirect hernias.

b, Imbrication of the external oblique beneath the spermatic cord, after the manner of Halsted, adds strength to the floor of the inguinal canal. This maneuver is employed in direct and in large indirect hernias in which the transversalis fascia is disrupted.

aspect of the inguinal canal, thus exposing the spine of the pubis at the transversalis level.

The cremasteric muscle and fascia are incised and the cord structures

are delivered from these investing membranes. The attachments of the cremaster are severed from the lateral and medial margins of the transversalis fascia constituting the internal abdominal ring. The cremaster fibers are dissected from the floor of the inguinal canal and are clamped and divided below the level of the pubic spine (Fig. 302). The direct defect in Hesselbach's triangle is thoroughly exposed.

The cord is placed on slight tension at the internal ring and the indirect sac is identified and opened. If no indirect sac is present, the normal reflection of peritoneum at the internal abdominal ring is grasped and opened. With an examining finger inserted into the peritoneal cavity an appraisal is made of (1) the size of the internal ring; (2) the status of the transversalis fascia in Hesselbach's triangle, and (3) the integrity of the femoral canal.

In indirect hernias, the sac is separated from the cord and the neck is closed with a purse-string suture. If the indirect sac is large, it is incised circumferentially at its neck and the distal portion is not removed. Direct sacs are converted into indirect ones, as advocated by Huguot.

The plastic reconstruction of the internal ring is accomplished by approximating the lateral and medial margins of the transversalis fascia with interrupted sutures of medium silk (Fig. 303, *insert*). Defects in the transversalis fascia overlying Hesselbach's triangle are closed by imbricating the structure with a row of similar sutures (Fig. 303). The floor of the inguinal canal is reinforced by approximating the dense aponeurotic structure which constitutes the lateral margin of the rectus sheath to the shelving edge of the inguinal ligament (Fig. 304). This maneuver is facilitated by the relaxing incision previously made in the rectus sheath. In indirect hernia with minor degrees of disruption of the transversalis fascia the external oblique aponeurosis is imbricated above the cord (Fig. 305, *a*). In direct hernia and in indirect hernia associated with loss of integrity of the transversalis fascia, the external oblique is sutured beneath the cord as described in Halsted's original operation (Fig. 305, *b*). Approximation of the skin and subcutaneous tissue with interrupted sutures of fine silk completes the procedure.

SUMMARY

Some pertinent anatomical considerations relative to inguinal hernias are discussed.

A method of repair is described.

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OPERATIVE PROCEDURES ON THE GALLBLADDER AND COMMON DUCT

BENTLEY P. COLCOCK

With the development of modern surgical facilities and technics, cholecystectomy has become one of the most frequently performed of intra-abdominal operative procedures. All surgeons of experience, however, particularly those who have been called upon to repair strictures of the common duct following cholecystectomy, decry the light-hearted attitude often manifested toward this operative procedure. The possibility of an immediate or eventual fatality as a result of irreparable damage to the hepatic artery, the portal vein and particularly the common duct is inherent in every cholecystectomy. Dr. Lahey has repeatedly emphasized the absolute necessity of an adequate exposure, a dry field, a good light and an accurate anatomical demonstration of the common, cystic and hepatic ducts, and hepatic and cystic arteries in all operative procedures in this area.

Surgery of the biliary tract has long been one of the major interests of this clinic. We believe that whenever gallstones can be demonstrated that patient should have removal of those stones, preferably by cholecystectomy. This includes the so-called silent stone. In our experience, patients with gallstones which have been asymptomatic, sometimes for years, may have serious complications develop, such as perforation, obstruction, secondary liver damage and pancreatitis. Many of the complications of cholelithiasis, such as acute cholecystitis, common duct stones, internal biliary fistulas, and so forth, occur in patients who have known that they had gallstones but have neglected to have their condition treated. If one is going to adopt a policy of advising cholecystectomy whenever the diagnosis of cholelithiasis can be established, one must have a plan of management that is associated with a minimum of morbidity and mortality. In a review of 1104 cases over a five-year period ending in December 1945 the mortality rate at the clinic was 0.9 per cent.¹

A second important characteristic of any technic for cholecystectomy should be an exposure which will permit opening and exploration of the common bile duct whenever any one of a number of indications is present. We now explore the common duct in 45.7 per cent of all cases of cholelithiasis with an incidence of common duct stone being found in 16.8 per cent. This means that we must not confine our indications for choledochostomy to the presence or history of jaundice. Forty-seven per cent of the 1104 patients previously referred to who were found to

have stones in their common ducts did not have jaundice. We are convinced from an experience of over 1500 explorations of the common duct that, in the hands of surgeons trained in the surgery of the biliary tract, choledochostomy does not increase the operative mortality or appreciably increase the operative morbidity.

A third and most important aspect of a technic for operative procedures on the gallbladder and common duct is that the exposure must be such that injuries of the hepatic artery, the portal vein and the common bile duct are reduced to an absolute minimum. We have now operated on more than 170 patients with benign stricture of the common bile duct. In 80 per cent of these patients the stricture was due to an operative injury which had occurred at the time of a previous cholecystectomy. These patients with stricture of the common duct present some of the most difficult problems to be found in abdominal surgery. Any patient who has an injury to his common bile duct faces a certainty of a long period of invalidism, the probability of one or more serious abdominal procedures and the very real possibility of a definitely shortened life. In over 5,000 gallbladder operations in this clinic only one operative stricture has been produced.

CHOLECYSTECTOMY FOR CHRONIC CHOLECYSTITIS AND CHOLELITHIASIS

1 In the absence of jaundice or acute symptoms, most of these patients will not require extensive preoperative preparation in the hospital. Most will have had a gastrointestinal study to rule out disease of the stomach, duodenum and colon.

Any associated cardiovascular disease should be treated as adequately as possible before the patient is scheduled for operation. These patients are placed on a high carbohydrate, high protein, low fat diet.

2. The preoperative medication for a healthy, vigorous patient under 50 years of age is pantopon, $\frac{1}{2}$ grain, and scopolamine, $\frac{1}{160}$ grain, subcutaneously two hours before operation, and 3 grains of a short-acting barbiturate orally one hour before operation.⁷ These doses are reduced for older and weaker patients and the patients over 60 are not given a barbiturate.

We believe that spinal anesthesia is the anesthesia of choice for all operations on the biliary tract. Not only does it provide the optimum exposure and relaxation so important for the surgeon when working in a deep wound in close proximity to such structures as the hepatic artery, portal vein and common duct, but, unlike deep general anesthesia, it has little or no deleterious effect upon the liver. This is important since many of these patients have long-standing hepatic damage secondary to their biliary tract disease. We have no concern relative to the use of

spinal anesthesia in the upper part of the abdomen since all anesthetics are given by a competent physician anesthetist and the level is accurately controlled by the use of a pontocaine-glucose mixture. For patients with common duct stricture, fractional spinal anesthesia, using pontocaine solution, is often employed. In addition to the spinal anesthesia, these patients are often carried under very light general anesthesia so that they will be oblivious to what goes on about them.

3. Incision. The type of operative incision is not important except that it must be of sufficient length to afford adequate exposure and admit adequate light to the region of the cystic duct, cystic artery and common duct in the depths of the wound. In an obese individual or patients with wide flaring costal margins, these structures may lie at considerable distance from the surface of the abdomen. At the clinic we use either a right rectus muscle splitting incision or a right paramedian incision, retracting the upper right rectus muscle.

4. Exploration. The peritoneal cavity is opened, and the abdomen is thoroughly explored. Most of our patients with disease of the biliary tract will have had a complete gastrointestinal study before coming to operation. Nevertheless, it is our custom to palpate carefully the liver, pancreas, kidneys, stomach, duodenum, colon and rectum before starting the cholecystectomy. If the exploration is negative and the diagnosis of cholelithiasis is substantiated by the presence of stones in the gallbladder, a Pennington clamp is placed on the gallbladder and the right lobe of the liver rotated downward and outward by breaking the suction between the dome of the right liver and right diaphragm. The stomach, duodenum and transverse colon are then retracted medialward and downward to the patient's left. When the duodenum and hepatic flexure are retracted to the left, the hepatic and common ducts are put on the stretch, the foramen of Winslow becomes visible, and one can obtain a clear view of all the important structures that must be dealt with during the course of the procedure (Fig. 306). Finally, before dissection is started, a gauze sponge is placed down to the region of the foramen of Winslow to collect any blood or bile which might escape and drain into the lesser peritoneal cavity.

With a second clamp placed on the ampulla, the gallbladder is put on the stretch, and a flap of peritoneum reflected on each side. Later, this will be used to peritonealize the gallbladder bed which we feel is important in preventing adhesions to the duodenum and pylorus with resultant disturbance in gastric function. Unless we are dealing with acute cholecystitis, we prefer to remove the gallbladder from below upward. Accordingly, our next step is to incise the peritoneum over the gastrohepatic ligament and isolate the cystic artery which is then clamped and divided. By securing the cystic artery first, three things

are accomplished: (1) the subsequent dissection is carried out in a relatively dry field, (2) when the cystic artery is divided and released from the gallbladder, the convolutions of the cystic duct can be straightened out and the junction of this duct with the common duct more clearly and accurately defined, and (3) it eliminates the danger of serious bleeding from tearing the cystic artery through traction on the gallbladder.

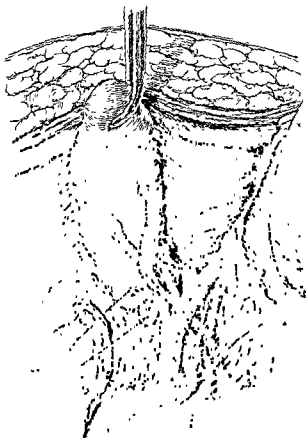


Fig 306 —Operative field The abdominal viscera are retracted to the patient's left, the gallbladder is retracted upward and to the right and the cystic artery and cystic duct will be exposed after reflection of their peritoneal covering. It will be noted that the cystic artery will have to be clamped and divided before the convolution of the cystic duct can be straightened out, permitting clear visualization of its junction with the common duct.

A careful review of the operative notes concerning the original cholecystectomy on patients sent to us for repair of common duct stricture indicates that serious bleeding from the cystic artery during the operative procedure was a frequent occurrence. Almost invariably in these patients the site of stricture in the common duct will be found close to the point where it is crossed by the cystic artery, strongly suggesting

that in securing hemostasis the common duct itself had been caught in the hemostats.

After the cystic artery has been divided and the cystic duct put on the stretch, its junction with the common duct is clearly demonstrated so that the cystic duct can be clamped, divided and ligated (Fig. 307). This is done at a point which will leave no stump of cystic duct in which

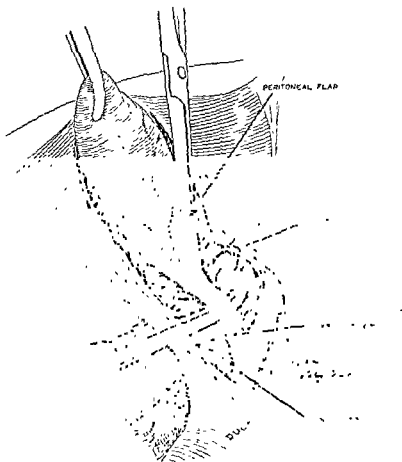


Fig. 307 —The flap of peritoneum has been reflected along each side of the gallbladder bed, the cystic artery divided and ligated and the junction of the common and cystic ducts isolated, permitting the latter to be divided and ligated flush with the common duct and the gallbladder removed from below upward

stasis and subsequent stone formation might occur and at the same time not cause any impairment of the lumen of the common duct. We feel strongly that the clamping of both cystic artery and cystic duct at one time with the same instrument is a practice which should be abandoned. After the cystic duct has been divided the gallbladder is then removed from below upward, with careful watch for any accessory blood vessels or accessory bile ducts which may enter either the cystic duct or gallbladder from the liver bed. We believe that it is the discharge from such

divided accessory bile ducts rather than a slipped ligature on the cystic duct which occasionally gives rise to biliary peritonitis. Since many of these small ducts will not drain bile immediately and are easily overlooked, we invariably add the additional safeguard of placing a Penrose or cigaret drain down to the foramen of Winslow at the completion of the cholecystectomy.

If choledochostomy is not indicated, the peritoneum of the gastrohepatic ligament is then approximated over the stump of the cystic stump and cystic artery and over the gallbladder bed. If the appendix is present, we routinely remove it provided it can be safely done through the existing incision. The incision is then closed in layers.

CHOLEDOCHOSTOMY

1. The various indications which, in our opinion, call for exploration of the common duct in patients with cholelithiasis have been reviewed elsewhere.¹ A surgeon operating on a patient for cholelithiasis must make very certain that the entire biliary tract is left free of calculi before completing the operative procedure. At the present time we explore the common duct in 45.7 per cent of all patients with cholelithiasis.

Fifty-three per cent of our patients who have common duct stones are jaundiced or give a history of jaundice and all patients with common duct stones should be assumed to have some degree of liver damage. If an appreciable degree of liver damage is present, these patients will require several days of preoperative preparation. Anemia must be corrected, the serum protein determined and restored to normal, or as near normal as possible. If jaundice is present these patients should receive from 4.8 mg. to 9 mg. per day of synthetic vitamin K by intramuscular injections. Vitamins A and B are also given since these patients are often deficient in this respect and the electrolyte balance, particularly serum chloride, should be checked and restored to normal limits before operation.

2. The same exposure which we believe is an essential part of a cholecystectomy will also provide adequate exposure for choledochostomy. The incision in the gastrohepatic ligament to expose the junction of the cystic and common hepatic ducts will expose the anterior surface of the common duct through which exploration is to be carried out. We do not believe that the common duct can be adequately explored through the stump of the cystic duct and for this reason a longitudinal incision is made on the anterior surface of the common duct just below the junction with the cystic. The suction tip is held close to the duct so as to prevent spillage of bile when the duct is opened. A sponge has already been placed in the foramen of Winslow to prevent any bile or blood draining

into the lesser omental cavity. The margins of the duct incision are held apart by long Allis type forceps, the teeth of which have been removed. The right and left hepatic ducts are first explored with the sound to demonstrate their patency. Scoops and forceps are then used to remove any stones or detritus from the lower end of the common duct. When we are satisfied that the common duct is clear, the ampulla of Vater is care-

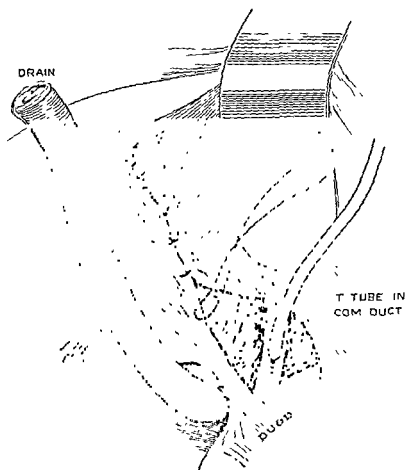


Fig 308.—The common duct has been explored below the stump of the cystic duct and the incision closed about an indwelling T-tube. The peritoneum will be approximated over the gallbladder bed and over the ligated cystic duct and artery and common duct. The drain is placed down to the foramen of Winslow.

fully dilated by graduated Bakes dilators to a size corresponding to that of the duct and any remaining sediment washed through into the duodenum by a catheter. No force is used in dilating the ampulla. As soon as the smallest dilator has gone through, the subsequent dilators are molded to the same curve and passed in the same direction until the desired dilatation has been obtained.

3. We do not close any common duct without drainage and we prefer a T-tube to a catheter for this purpose (Fig. 308). If fibrosis and stenosis

of the ampulla have been found, a long arm T-tube² with one limb of the T passed through the ampulla well down into the duodenum is used to maintain the dilatation of the ampulla until all danger of secondary constriction is passed. These long arm T-tubes are often left in for six to nine months.

4 For the average patient a tube with the cross arm cut very short is inserted and the incision in the duct closed about it by fine interrupted sutures. The T-tube is clamped for one hour on the seventh postoperative day and this period is doubled each day until it is clamped continuously. If the patient's stools have resumed their normal color it is removed about the twelfth postoperative day. If there has been marked dilatation of the common duct or evidences of severe cholangitis, the T-tube may be left in for as long as three to six months. If many stones have been found in the common duct, a cholangiogram is usually made before the T-tube is removed to make certain that no stone has been overlooked or has passed down from the intrahepatic portion of the biliary tree following the choledochostomy. If the patient is being sent home with the T-tube in, he is instructed either to open the T-tube at night and allow it to drain into a bottle at the side of the bed or to irrigate the tube twice a day to maintain patency.

5. Choledochostomy has not increased the mortality or appreciably affected the morbidity following cholecystectomy, and the advisability of exploring the common duct should be carefully considered in every patient subjected to cholecystectomy for cholelithiasis.

COMMON DUCT STRICTURE

Stricture of the common duct as a result of injury to the duct during the performance of cholecystectomy presents one of the most difficult problems encountered in abdominal surgery. We have had considerable experience with these patients and this experience has been reviewed in detail by Lahey⁵ and by Cattell.² The most important aspect of this problem is its prevention and the value of good anesthesia, adequate exposure and careful anatomical dissection in the prevention of common duct stricture has already been emphasized.

As Lahey has pointed out, the prospect of obtaining a good surgical result in these patients who have a stricture of the common duct will depend upon the type of injury to the duct, whether or not a previous attempt at repair had been made and whether irreparable liver damage has occurred as a result of repeated and long continued obstruction and infection of the biliary tract. Cattell² has pointed out that two general methods of repair are available; first, anastomosis of the proximal end of the duct to the gastrointestinal tract, that is duodenum or jejunum, and second, restoration of continuity of the duct by suture at the proxi-

mal and distal ends over a tube preserving the normal sphincteric action at the lower end of the duct. In our experience, repair by the second method is the method of choice and will give the best results whenever it can be accomplished. He has pointed out that frequently this can be accomplished, even though there is apparently no lower segment of common duct remaining, by completely mobilizing the first and second portions of the duodenum and occasionally splitting the head of the pancreas in order to develop the undamaged lower portion of the common duct for anastomosis to the upper end over one arm of a T-tube. It is

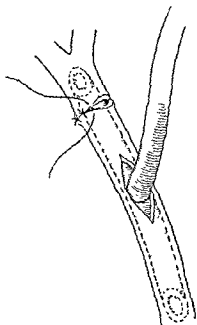


Fig. 309.—This illustrates the most desirable type of repair following stricture of the common duct. An end-to-end suture of the duct itself is being carried out, thus preserving the sphincter mechanism at the ampulla. The T-tube will maintain the patency of the anastomosis until all danger of narrowing of the anastomosis is passed. It should be noted that the long arm has been brought out the normal portion of the common duct so that its withdrawal will not affect the area of anastomosis.

important not to bring the vertical limb of the T-tube out at the site of the anastomosis but through an incision in the duct below this point so that its subsequent removal will not damage the suture line (Fig. 309). These tubes are left in place for at least six to nine months.

CHOLECYSTECTOMY FOR ACUTE CHOLECYSTITIS

1. In acute cholecystitis we believe that surgery as soon as the patient's general condition will permit, preferably within forty-eight hours following the onset of symptoms, will be associated with a lower mortality and lower morbidity rate than will the policy of waiting until the acute process subsides. These patients should be admitted to the hospital

promptly, fluids and glucose by vein started immediately, and operation carried out as soon as any existing dehydration or disturbed blood chemistry has been restored to as near normal as possible. In a series of 74 pathologically proved cases of acute disease of the gallbladder reported in 1948, there was one postoperative death, a mortality of 1.3 per cent ⁴

2 The usual cholecystectomy incision is made and the usual exposure obtained. The edema in the gallbladder wall usually prevents any attempt at the reflection of peritoneal flaps with which to reperitonealize the gallbladder bed. Contrary to our usual custom of retrograde removal of the gallbladder, in most of these patients we feel it is safer to dissect the gallbladder from its bed beginning at the fundus and proceeding down to the cystic artery and common duct, because of the amount of edema surrounding these important structures.

In patients with markedly distended gallbladders, better exposure of the cystic artery and duct may be obtained by first emptying the gallbladder with suction. The fundus is punctured with the trocar suction tip and when the gallbladder is empty the puncture wound can be closed by a clamp as the suction is withdrawn, preventing any spillage of bile.

3 Common duct stone as a complication of acute cholecystitis is not uncommon and in the previously reported series of 74 patients, a common duct stone was found in 16.8 per cent. In other words, common duct stones are just as frequently found associated with acute cholecystitis as with chronic cholecystitis, and the exposure and dissection should be such in these patients as to permit cholecystostomy when indicated just as when operating for chronic cholecystitis and cholelithiasis.

4. Whenever possible we prefer to carry out cholecystectomy for acute cholecystitis. Occasionally, because of the patient's condition, it may be necessary to do only a cholecystostomy. In these patients, the fundus is exposed and carefully walled off from the rest of the peritoneal cavity. A small incision is made in the dome of the fundus and the gallbladder emptied. The margins of the incision are then held open by Allis forceps and scoops and gallbladder forceps used to empty the gallbladder of stones. Occasionally the only stone present will be a small one wedged far down in the cystic duct. This should be removed if possible. A large catheter is then placed in the opening of the gallbladder and the opening closed about it by two or more inverting purse-string sutures. The catheter is then brought through the omentum and out through the upper portion of the incision.

5. Patients with acute cholecystitis are usually given penicillin postoperatively. At the present time we are using 300,000 units given in one injection daily (crysticillin). Many of these patients are aged and may

have associated cardiovascular disease. They should be carefully watched from this point of view following their operative procedure.

SUMMARY

Gallbladder surgery is major surgery. It should not be attempted by the occasional operator or by any surgeon who is handicapped by insufficient experience or inadequate facilities. When performed by a competent surgeon with good light and adequate exposure, it is associated with a low morbidity and mortality rate, and is a credit to modern abdominal surgery.

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RESECTION OF THE SMALL INTESTINE

KENNETH W. WARREN

RESECTION of the small intestine, particularly when performed in the absence of obstruction, is considerably less hazardous than resection of the colon. Factors which contribute to this relative safety in the segmental removal of the small bowel include (1) mobility, (2) rich collateral vascular supply, (3) well developed submucosal and muscular coats, and (4) less infectious intestinal contents.

When obstruction is present, surgical manipulation of the small intestine may present a real challenge to surgical judgment and technical skill. Frequently, the choice of the proper time to operate and the election of an appropriate method of resection in instances of small bowel obstruction are requisite to a successful outcome.

GENERAL CONSIDERATIONS

The functional reserve of the small intestine is great and this factor permits of a generous sacrifice of the bowel in those pathologic states wherein wide excision is indicated, as in malignant disease and chronic nonspecific enteritis. It is important, in the latter condition, to search the entire intestine for "skip" areas of involvement and to resect well beyond the obvious limits of the disease.

Lesions of the small intestine are frequently obscure and their detection may require minute inspection of the entire structure, from the ligament of Treitz to the ileocecal valve.

PREOPERATIVE PREPARATION

The profound disturbances in fluid, electrolyte and nutritional balance in the presence of intestinal obstruction require vigorous restorative measures. Time spent in the restoration of normal blood volume and chemical values prior to surgery is often reflected in lowered mortality figures.

Intestinal intubation, in both the obstructed and nonobstructed bowel, is of inestimable value. In the presence of obstruction, the indwelling Miller-Abbott tube will effect some measure of decompression before surgery, it will afford safer manipulation of the bowel during the operation and will present a means of further decompression of the distended bowel by being advanced manually by the operator as constant suction is applied. In this manner one may obviate the more dangerous procedure

of enterostomy decompression as a preliminary to resection. The Miller-Abbott tube will protect the suture line following the operation.

METHODS OF RESECTION

A wide variety of technics¹ is available for small intestinal resection and the choice of a procedure should be determined by a consideration of (1) the location of the lesion (particularly those near the ligament of Treitz or the ileocecal valve), (2) the presence or absence of obstruction and (3) the familiarity of the operator with a particular technic. The vehemence of the argument in certain quarters regarding the superiority of the "closed" or aseptic over the "open" method, or vice versa, is disproportionate to the relative merits of either. The essential problem is to master a few procedures which, as a group, are applicable to the entire gamut of situations which will demand small bowel resection. In this mastery of a limited number of technics, I believe, it should be recognized that in certain situations a particular method is superior to another method which the operator might, under more usual circumstances, prefer to employ. It is, for instance, easier and safer to employ an end-to-end open anastomosis in resection of the small intestine when the lesion is near the ligament of Treitz or the ileocecal valve, provided no great disproportion between the caliber of the proximal and distal bowel exists. By the same token, it is impossible to approximate the greatly distended proximal segment of bowel to the deflated portion of distal intestine by end-to-end anastomosis. This disparity in relative size of the lumen of two portions of the bowel to be joined may also preclude the employment of the clamp method of aseptic anastomosis.

Resection of the small intestine by exteriorization is a procedure which is no longer widely employed, but is of some merit and it should be resorted to in certain desperate situations when the exigencies of the moment dictate a minimum of surgical manipulation.

It is noteworthy in this regard that Gross and Ware, who have had a considerable experience with intestinal resection for irreducible intussusception in infants, prefer resection by exteriorization to primary anastomosis in this very hazardous situation. Although the present author is on record² as partial to the principle of immediate restoration of the continuity of the intestine in irreducible intussusception, one should not ignore the availability of the simpler method of resection by exteriorization.

Despite one's acquired preference for a certain method of small bowel resection it is reasonable to contend that a lateral anastomosis by the open method is, perhaps, the simplest and safest procedure to employ if one wishes to apply a single technic to the widest variety of lesions of the small intestine. This method avoids all manipulation of the mesenteric

border during the fashioning of the stoma. All sutures are placed under direct vision which insures careful approximation and adequate hemostasis, with no possibility of an obstructing septum which is possible with the closed clamp technic. An adequate stoma is more definitely insured.

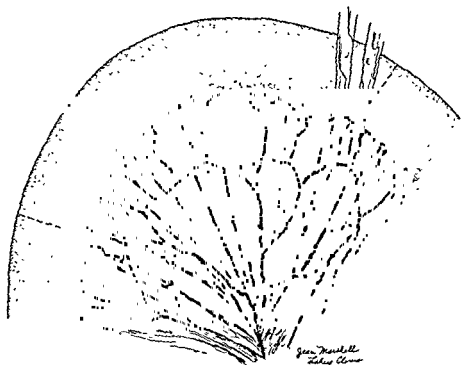


Fig 310 —The mesenteric vessels supplying the segment of bowel to be resected are divided between clamps after the peritoneal covering on each side of the mesentery has been incised.

TECHNIC

Spinal anesthesia is preferable unless some compelling contraindication to its use is present.

The abdomen is generally entered through a vertical, muscle retracting or muscle splitting incision in the particular quadrant where the disease is anticipated. In the absence of an acute emergency, the entire abdominal cavity is carefully explored. The lesion is inspected and the limits of resection are determined. The peritoneum on each side of the mesentery is incised in a wedge-shaped fashion, as indicated in Figure 310. The individual vessels are divided between small straight hemostats and are carefully ligated. The points of election for division of the bowel are cleared of all mesenteric fat. The decision is then made with respect to the type of anastomosis that is to be accomplished, and the details of the remainder of the procedure are pursued in accordance with the manner of restoration that has been selected.

End-to-end "Open" Anastomosis.—Paired Ochsner clamps are applied to the two areas of intestine previously prepared, the bowel is divided with the live cautery and the segment containing the lesion is discarded.

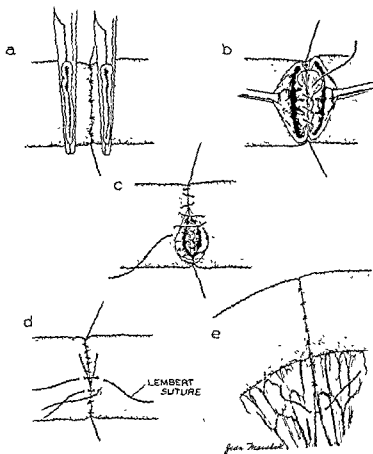


Fig. 311 —End-to-end open anastomosis

a, The proximal and distal segments of the divided intestine are apposed with a row of interrupted silk sutures

b, The clamps have been removed and the anterior margins of the intestine have been retracted with Allis forceps. The posterior margins of the stoma are approximated with a continuous interlocking suture of chromic catgut.

c, The posterior suture is continued anteriorly as a Connell suture, inverting the anterior

closure.

The proximal and distal segments to be united are held in close proximity and the posterior or mesenteric surfaces are approximated with interrupted sutures of fine silk (Fig. 311, *a*). The clamps are removed and the

second posterior row of sutures, consisting of a continuous, interlocking strand of medium chromic catgut, is placed through all layers (Fig. 311, *b*). This suture is continued anteriorly, after the manner of Connell, as a through-and-through inverting suture (Fig. 311, *c*). The anterior portion of the anastomosis is completed by the application of a row of Lembert sutures of fine silk. The defect in the mesentery is closed by approximating the peritoneal edges on each side of the mesentery by continuous fine catgut or interrupted silk sutures (Fig. 311, *e*).

Lateral Open Anastomosis.—The bowel is divided between paired clamps and the proximal and distal ends are closed with a continuous suture of chromic catgut (Fig. 312, *a*), and inverted with a row of Lembert sutures of fine silk. The two ends of the divided intestine are then overlapped for a distance of approximately 3 inches, and the apposing walls are united near the mesenteric borders with a row of interrupted sutures of fine silk (Fig. 312, *b*). Parallel openings are made in each segment of bowel about 1 cm. from the previously placed line of sutures. The posterior margins of the stoma are approximated with a continuous interlocking suture of chromic catgut (Fig. 312, *c*), which suture is continued anteriorly as a Connell suture, inverting the anterior margins of the stoma. The anterior closure is completed with an additional row of Lembert sutures of fine silk (Fig. 312, *d*). The overlapping mesentery is closed on each side with a continuous suture of fine catgut.

It is essential that the closed ends of the intestine do not project to any considerable degree beyond the margins of the stoma if mild obstructive symptoms are to be avoided.

An alternative method of open lateral anastomosis is that described by Halsted and modified by Finney. In this procedure the two segments of intestine are apposed with a row of interrupted sutures of fine silk, as in the method described above. The anchor suture at one angle of the prospective stoma is placed in the groove formed by the apposed surfaces of the intestine. A series of interrupted sutures of fine silk is now placed in the two segments of intestine in the following fashion. Beginning as a Lembert suture approximately 1.5 cm. from the row of previously placed sutures and continuing to the opposite segment of bowel as a lateral mattress suture equidistant from the original suture line, the stitch is completed as a Lembert suture on the original segment of bowel from whence the stitch began. A series of similar sutures is placed until one half of the length of the proposed stoma has been traversed. These sutures, which are left untied, are drawn out of the field and the other half of the row of sutures is placed in a similar fashion. Parallel openings are made opposite one another in the apposed segments of bowel, between the parallel rows of sutures, and the posterior margins of the stoma are approximated with a continuous interlocking suture of chromic catgut

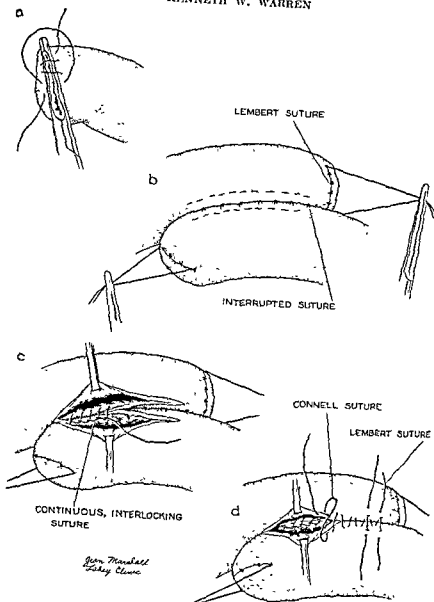


Fig 312 —Side-to-side open anastomosis

a, Each end of the divided bowel is closed over the clamp with a simple inverting suture of chromic catgut, and reinforced by interrupted Lembert sutures of fine silk (b)

b, The proximal and distal segments are overlapped for a distance of 3 inches and united near their mesenteric borders with a row of interrupted silk sutures

c, Openings are made in the two segments of apposed bowel, parallel to and about 1 cm distant from the row of previously placed sutures. The posterior margins of the stoma are

sutures. The mesenteric defect (not shown in illustration) is closed by a row of interrupted sutures on each side of the overlapping mesenteric margins

(Fig. 313, *a*). The previously placed anterior sutures are now drawn taut in unison, thereby inverting the anterior margins of the stoma. These sutures are tied individually. A second anterior row of Lembert sutures of fine silk may be employed to reinforce the closure (Fig. 313, *b*).

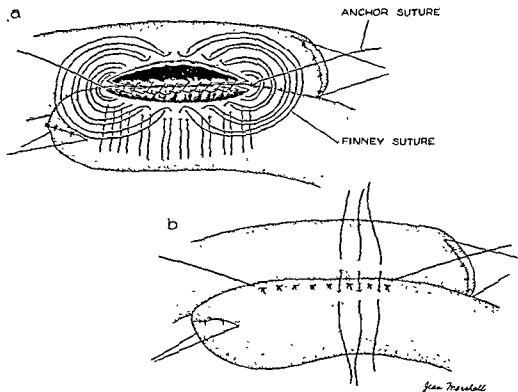
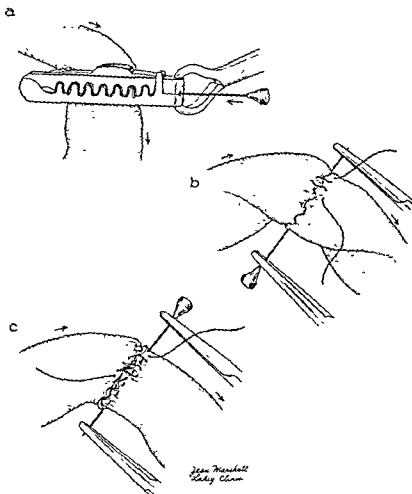


Fig. 313 —Alternate method of side-to-side open anastomosis. The ends of the divided bowel are inverted and the proximal and distal segments are overlapped and united with a row of interrupted sutures of silk, as described and illustrated in Figure 312, *a* and *b*

a, Before the parallel openings are made in the apposed segments of intestine the first row of anterior sutures is placed in the following fashion. Beginning as a Lembert suture on one segment of the apposed bowel, about 1.5 cm. from the row of previously placed sutures and continuing to the opposite segment of bowel as a lateral mattress suture equidistant from the original suture line, the stitch is completed as a Lembert suture on the original segment of bowel from whence it began. These sutures, all of which are left untied, are drawn out of the field as indicated and parallel openings are made in each segment of the intestine. The posterior margins are approximated with a continuous interlocking suture of chromic catgut (*b*). The previously placed anterior row of sutures is now drawn taut in unison and tied individually. A row of Lembert sutures may be used to reinforce the anterior closure.

The rent in the mesentery is closed as in the previously described method of lateral anastomosis.

End-to-end Aseptic Method Employing Furniss Clamp.—This method is most applicable when the proximal and distal segments of intestine are of equal caliber and of unrestricted mobility. The points of division are



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Fig. 314 —End-to-end closed anastomosis employing Furniss (McClure) clamp

a, The McClure modification of the Furniss clamp has been applied to the proximal and distal segments of bowel and the diseased portion has been removed. The needle is being inserted into the "eye" of the clamp in order to transfix and secure the cut margins of the intestine.

b, The clamp has been removed and the needle, which transfixes the serrated margins of the bowel, has been rotated through 180 degrees, thus bringing the posterior surfaces of the segments of intestine into the anterior plane. A continuous suture of fine chromic catgut, tied at its beginning point and locked at its termination, unites the posterior surfaces of the divided bowel.

c, The transfixion needle has been rotated back through 180 degrees to the original position. Another continuous suture of fine chromic catgut approximates the anterior margins of the intestine. The appropriate ends of the anterior and posterior sutures are tied together at each angle, after the transfixion needle has been withdrawn.

prepared as above. The Furniss clamp, or preferably the McClure modification of it, is applied to the proximal and distal segments of the bowel as they are held in close apposition to one another. A straight needle is

inserted into the "eye" of the clamp, thereby transfixing the serrated portion of the bowel held in the clamp. Ochsner clamps are then applied to the proximal and distal ends of the segment of bowel that is to be removed and the intestine is divided with the live cautery (Fig. 314, *a*). The Furniss clamp is removed, leaving the ends of the bowel to be joined secured by the transfixion needle which, in turn, is rotated through 180 degrees. This maneuver brings the posterior walls of the prospective stoma into the anterior plane, where they are united by a continuous row of fine catgut (Fig. 314, *b*). The transfixion needle is now rotated

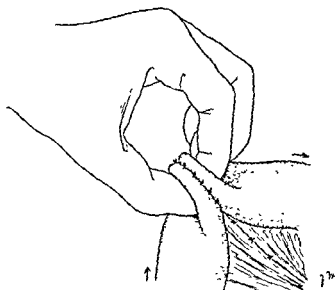


Fig. 315.—The agglutinated edges of the divided bowel are separated by invaginating the anterior wall of the intestine through the new stoma. The anastomosis is then reinforced by a row of interrupted Lembert sutures of fine silk around the entire circumference of the bowel and the mesenteric defect is closed with a series of similar sutures. One may prefer to employ a double row of Lembert silk sutures for this method of anastomosis.

back through 180 degrees to the initial position and the anterior walls of the apposed ends of the intestine are approximated with a continuous suture of fine catgut (Fig. 314, *c*). The transfixion needle is withdrawn and the agglutinated edges of the intestine are separated by gentle digital pressure, thus restoring the continuity of the lumen of the bowel. A row of interrupted Lembert sutures of fine silk, encircling the new stoma, completes the anastomosis (Fig. 315). The mesenteric defect is closed in the manner described above.

This technic, in general, is applicable to the utilization of a variety of specialized clamps designed for the accomplishment of aseptic anastomosis of the gastrointestinal tract. They may, in turn, be similarly employed for lateral anastomoses.

Mikulicz Resection of the Small Intestine.—The mobilization and

preparation of the points of division of the intestine for resection by the method of exteriorization are identical with these maneuvers preliminary to resection and immediate anastomosis. When the Mikulicz method is dictated by circumstance, the segment of bowel to be removed is divided between paired clamps by the live cautery. The proximal and distal limbs are apposed in double barrel fashion with the proximal end projecting beyond the distal end by 2 cm. and a spur is formed by a double row of interrupted sutures of fine catgut, uniting mesenteric segments of the bowel. The abdominal wall is closed in layers about the exteriorized intestine. A dressing is applied, leaving the proximal segment of intestine exposed in order that it may be decompressed as a final step in the procedure. Thus decompression is accomplished by inserting a soft flexible catheter of appropriate size into the proximal loop below the peritoneal level. The catheter is anchored in position by a previously placed purse-string suture of chromic catgut.

The spur, in ordinary circumstances, is crushed by serial clamps, beginning about the seventh postoperative day. The restoration of intestinal continuity is accomplished surgically, approximately eight weeks after the initial resection.

This method of resection has a limited range of application today, but to ignore its existence is to deny the occasional patient who is desperately ill his most reasonable chance of recovery.

POSTOPERATIVE CARE

Constant suction is maintained on the indwelling Miller-Abbott tube until flatus is passed freely. It should be borne in mind, in this regard, that the Miller-Abbott tube, with its suction tip beyond the pylorus, does not necessarily decompress the stomach and that it is therefore wise, in some instances, to employ separate gastric suction via a Levin tube in addition to the intestinal siphonage.

Parenteral fluids, including adequate amounts of glucose, saline, amino acid preparations and whole blood, are administered until adequate oral alimentation is feasible.

Prophylactic or therapeutic doses of penicillin, according to clinical indications, are systematically employed.

Graduated diet and ambulation are varied according to individual tolerance.

SUMMARY

General considerations relative to resection of the small intestine are discussed.

Various techniques of small intestinal resection are described.

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PRIMARY RESECTION OF THE COLON

BENTLEY P. COLCOCK

Like most surgeons interested in carcinoma of the colon we have found that an increasing number of patients with malignant disease of the large bowel can be submitted to resection and intestinal continuity immediately restored by a primary anastomosis. In our hands, the percentage of two-stage operations for carcinoma of the colon has steadily decreased in recent years.

Ten years ago all patients treated in the clinic for malignant disease of the colon had a modified Mikulicz type of procedure.² We demonstrated to our satisfaction, at least, that this procedure was as radical in its scope as any operative procedure for carcinoma of the colon and that it was associated with a lower incidence of the most serious complication of colon resection, namely, peritonitis, than was primary anastomosis. We believe this is still true for the patient with a perforated lesion or the patient in whom distention of the bowel, excessive fat in the adjacent mesentery or a questionable blood supply to the divided end of the bowel makes satisfactory healing of the anastomosis less certain. It has long been accepted that when peritonitis does follow a primary resection and anastomosis of the colon, it is the result of contamination not by bowel content at the time of operation but usually from a leak at the suture line following the operative procedure. Excessive fat in the adjacent mesentery and epiploic appendages makes accurate serosa-to-serosa approximation difficult. If any segment of the divided margin of either limb of bowel is devitalized, necrosis and leakage from the suture line will inevitably occur. A segment of colon dilated and hypertrophied as the result of long-standing obstruction always makes primary closure more hazardous. A modified Mikulicz procedure for carcinoma of the colon can be adapted to these unfavorable cases as well as the favorable cases and in our experience can be as readily carried out on the right half of the colon (with the formation of a double-barreled Mikulicz ileocolostomy spur) as on the left colon. When a two-stage procedure is indicated, this type of operation has two definite advantages over other two-stage procedures in that the malignant lesion is eliminated at the first operative procedure and the second stage of the procedure is an extraperitoneal operation.

In 1945, 40 per cent of 40 patients with carcinoma of the cecum, ascending colon and right half of the transverse colon had resections with a primary anastomosis.¹ At the present time all patients with carcinoma of the right colon except those with complications which are

known to increase the risk of primary resection of the colon are submitted to resection with primary anastomosis. The same is true to a less extent of patients with carcinoma of the left colon, namely, the distal transverse colon, splenic flexure, descending colon and sigmoid. Here the incidence of obstruction of the colon with dilatation of the proximal bowel is greater and it is often not possible to achieve satisfactory decompression of the proximal bowel by the usual preoperative preparation. If the obstruction is complete and the distention acute, an emergency cecostomy or proximal transverse colostomy must be considered. If the obstruction is moderate or can be partially relieved by the preoperative preparation, these patients may be more safely resected by the modified Mikulicz type of procedure than by resection with primary anastomosis.

Another factor which must be kept in mind relative to patients with carcinoma of the left colon is that the lumen of the bowel is smaller on this side than it is in the right colon. The diameter of the lumen in the descending colon and sigmoid is the smallest of the entire colon. Obstruction at the point of anastomosis following primary resection and suture has been reported even by surgeons experienced in colon surgery and all have emphasized the danger of excessive constriction of the lumen by end-to-end suture in this segment of the large bowel. The diameter of the lumen at the point of anastomosis following the modified Mikulicz procedure is actually greater than normal and obstruction, either early or late, does not occur following this procedure.

SURGICAL PRINCIPLES

Preoperative Preparation.—A large share of the credit for the increased safety of the one-stage primary resection of the colon is due to an increase in the attention which is paid to the preoperative preparation of both the patient in general and his colon in particular.

Most of these patients who have had melena or a disturbance in their normal bowel function will have some degree of anemia and a decreased serum protein. In patients with carcinoma of the cecum this anemia is often severe and at times is the only symptom of the underlying disease. A low serum protein in itself can precipitate sufficient edema at the site of anastomosis to produce postoperative obstruction. Consequently, it is essential that the hemoglobin, red blood count and serum protein be restored to as near normal as possible before these patients are operated on. This can best be accomplished by transfusion of adequate amounts of whole blood. Nonprotein nitrogen and chloride levels of the blood should be checked and the electrolyte balance restored to normal. Any associated cardiovascular renal disease should be carefully evaluated

and treated, if necessary. If there is a previous history of thrombosis of the deep venous system of the lower extremity, the need for prophylactic femoral ligation or the postoperative use of anticoagulant therapy should be kept in mind. Our own policy is to place these patients on a heparin-Dicumarol regimen as soon as the danger of postoperative bleeding is past, usually about the third postoperative day. (Of 10,700 operations of all types during 1947, there were but 2 postoperative deaths from pulmonary embolism.)

Before the active preparation of the bowel itself is started, these patients should be carefully examined to determine any degree of obstruction that may be present. In patients who have complete obstruction it is our policy to carry out an emergency cecostomy. A Miller-Abbott tube will decompress the small bowel but it will not relieve the closed loop of obstructed colon between a competent ileocecal valve and a constricting carcinoma of the descending colon or sigmoid. In our experience, the most efficient type of cecostomy is that in which the lateral attachments of the cecum are divided and a portion of the cecal wall itself is exteriorized through a right lower quadrant incision (Fig. 316). This type of cecostomy will adequately decompress any obstructed bowel and will remain open as long as is necessary. After the incision has been closed and the dressings applied, a large mushroom catheter is placed in the exteriorized segment of cecum by purse-string sutures. This catheter is removed in a few days and irrigation of the obstructed segment of bowel carried out. Later, following resection of the malignant growth, the cecostomy is closed by an extraperitoneal procedure.

In patients with moderate degrees of obstruction, careful examination of the abdomen, often aided by a roentgenographic film ("flat-plate"), will enable one to determine whether it is safe to give a cathartic by mouth. Unless contraindicated by obstruction, we give all patients with carcinoma of the colon $1\frac{1}{2}$ ounces of magnesium sulfate by mouth and follow this with high colonic irrigations twice a day. It should be mentioned at this point that in any patient in whom an obstructing lesion of the colon is suspected, it is important to carry out the barium enema part of the gastrointestinal examination first. The administration of barium by mouth to a patient with partial obstruction may produce an acute complete obstruction.

In all patients with malignant disease of the right colon, that is, the cecum, ascending colon and proximal transverse colon, in whom the resection will be followed by an anastomosis of ileum to a distal segment of colon, a Miller-Abbott tube is inserted well down into the small bowel before they come to surgery. This is a valuable adjunct in patients of this type and permits excellent decompression of the area of anastomosis for as long as may be necessary. The Miller-Abbott tube

may also be used in patients with carcinoma of the left colon but it must be remembered that in these patients, who will have an anastomosis of the left side of the colon, we cannot expect the Miller-Abbott tube to do more than counteract distention of the small bowel. In order to decompress the area of anastomosis in these patients the tube would have to pass through the ileocecal valve into the colon itself. This it will usually do if given sufficient time. However, two possible complications must be kept in mind if the tube is allowed to progress this far. In the first place, gastric dilatation may occur following operation and a second tube may have to be introduced into the stomach. In the second place, it is sometimes difficult or impossible to withdraw an intestinal tube

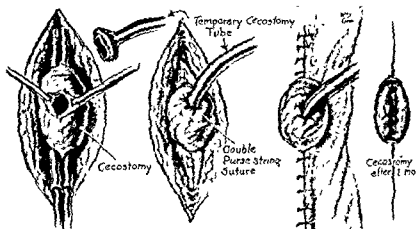


Fig 316 --The cecum has been mobilized so that it can be exteriorized without tension. The wound is closed loosely about the cecum, protected by a dressing and a de Pezzer catheter inserted. The cecostomy opening can later be closed by an extraperitoneal procedure.

which has passed through the ileocecal valve, particularly if mercury has been placed in the bag.

All patients who are scheduled for resection of the colon are placed on sulfathalidine for three to five days before operation. It is our practice to give 2 gm. of the drug four times a day. We feel that this has been of definite help in decreasing the risk from any contamination which may occur at the site of the open anastomosis. We have not used streptomycin in the preparation of these patients because we have not felt it was necessary. If it is used it must be remembered that its peak of effective action is limited and operation should be carried out at this time (twenty-four to forty-eight hours after administration) if the drug is to be of value.

Adequate Mobilization.--Any surgeon who has had extensive experience with an exteriorization procedure for resection of the colon, such

as the modified Mikulicz operation, appreciates the necessity of adequate mobilization of the colon so that the lesion may be resected widely, and the loops exteriorized without tension. It is equally important, if not more so, that sufficient mobilization be carried out before an attempt is made to approximate the two ends by intraperitoneal suture. Tension on the suture line as the result of insufficient mobilization of the bowel will definitely increase the risk of leakage and the development of local or generalized peritonitis.

Adequate Blood Supply to the Anastomosis.—The necessity of preserving adequate blood supply to the divided end of each loop of bowel forming part of the anastomosis has already been pointed out. Necrosis at the suture line has been one of the most common causes of leakage following primary suture of the large bowel. The origin and course of the main colic arteries must be kept in mind when the line of resection is determined. Because of individual variation in the size and course of the arterial blood supply to the colon it is also important to see or feel pulsating vessels supplying the divided ends of the bowel which are to be united. The bowel wall itself is supplied by long and short terminal branches of the main colic arteries. The antimesenteric border of the bowel is supplied only by the long terminal branches and is the portion of the circumference of the bowel which is most likely to be devitalized. If an attempt is made to remove epiploic appendages in order to secure more accurate apposition of the cut margin of the bowel, it should be remembered that these long terminal branches supplying the antimesenteric border often loop up into the base of these epiploic appendages as they pass around the circumference of the bowel. Dividing the bowel somewhat obliquely so as to remove more of the antimesenteric portion is an additional safeguard in securing good healing in this region. If the viability of the bowel or the integrity of the suture line is questionable a proximal transverse colostomy should be carried out. If the bowel is completely divided at this point it will defunctionalize the region of the anastomosis, and may prevent leakage and peritonitis. After sufficient time for secure healing has elapsed, the patency and integrity of the anastomosis can be demonstrated by barium enema examination and the proximal colostomy closed.

Adequate Cancer Operation.—When operating upon a patient for carcinoma of the colon one must always remember that the primary purpose of the operative procedure is to cure him of his disease, if possible. The method by which intestinal continuity is to be restored is definitely a secondary consideration and it should never be allowed to influence the extent of the resection. An adequate cancer operation includes removal of an adequate margin of normal bowel on each side of the lesion. It also implies a radical resection of the mesentery of that

segment of bowel which contains the malignancy. As a rule, metastatic malignant disease first occurs in the lymph nodes of this mesentery and, in general, these lymph nodes follow the course of the major blood vessels. This means that the major blood vessels must be divided close to their origin from the superior and inferior mesenteric arteries. This wide and deep resection of the adjacent mesentery is important for a second reason. In recent years the frequency and serious prognostic significance of blood vessel invasion by malignant disease of the colon has become well known. A radical resection of the mesentery will include as extensive a removal as possible of the venous channels draining the region of the growth.

TECHNIC

Carcinoma of the Cecum, Ascending Colon, Hepatic Flexure and Proximal Half of the Transverse Colon.—A careful study of resected specimens has demonstrated that malignant lesions of the hepatic flexure and proximal portion of the transverse colon frequently metastasize to the lymph nodes along the course of the ileocolic artery. For this reason radical resection of malignancy in this area should include the terminal ileum, cecum and ascending colon along with its lymphatic and venous drainage just as is carried out in patients with carcinoma of the cecum and ascending colon.

Pontocaine-glucose spinal anesthesia is used for all patients unless there is a definite contraindication. Immediately after the spinal anesthesia has been given, an intravenous infusion is started in an ankle vein and all patients receive at least 500 cc. of whole blood during the operative procedure.

A right rectus or right paramedian incision is used and it must be of sufficient length to afford good exposure of the entire right colon and terminal ileum. Before resection is started the abdominal cavity is thoroughly explored. The liver should be carefully inspected by direct vision and by palpation to rule out metastatic involvement, and the rectum and left half of the colon carefully palpated to rule out a second primary malignancy. In our experience, multiple malignancies have occurred in 4 per cent of all patients with carcinoma of the colon.

The small bowel is retracted to the left side of the abdominal cavity and, with tension on the cecum and ascending colon, the lateral peritoneal reflection is divided along the adjacent 10 to 12 inches of terminal ileum, the cecum and ascending colon and around the hepatic flexure. This dissection is extended medialward behind the mesentery of the right colon, carefully reflecting the right ureter and the retroperitoneal portions of the duodenum (Fig. 317). The right ureter can often be

quickly identified by its course parallel to and just medial to the right spermatic or ovarian vessels. This entire mobilization can usually be carried down to the root of the mesentery with the division of only a few blood vessels in the region of the hepatic flexure attachment. The importance of this initial mobilization of the right colon and its mesentery,

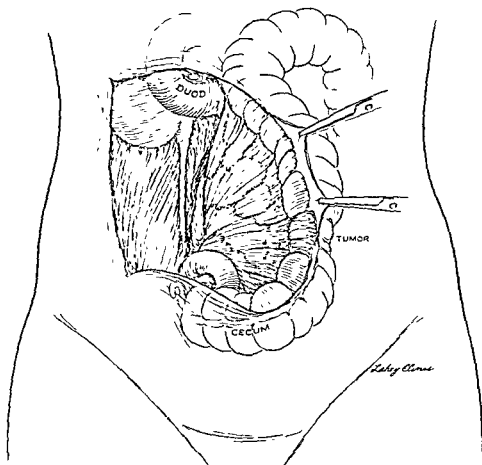


Fig 317.—The peritoneum has been divided along the line of fusion of the visceral and parietal peritoneum. This will be carried around the hepatic flexure, mobilizing the proximal half of the transverse colon. The bowel is mobilized medialward. Spermatic or ovarian vessels will come into view and the ureter will be found just posterior and medial to these vessels. In the upper angle of the wound the retroperitoneal portion of the duodenum will be drawn up with the colon and must be carefully reflected posteriorly. For tumors in this location the bowel must be mobilized medialward to a point where the ileocolic, the right colic and the right branch of the middle colic arteries can be divided close to their origin.

not only to permit a sufficiently radical removal of the tumor and its mesentery but also to permit satisfactory and safe restoration of the intestinal continuity, has already been emphasized.

With the mobilized colon retracted to the right, the peritoneum over the medial surface of the mesentery is then divided in a line leading from a point on the small bowel well below the lesion down to the root

of the mesentery close to the origin of the ileocolic and right colic vessels and then upward to a point on the transverse colon well beyond the lesion. *The blood vessels are divided along this line and the terminal ileum and transverse colon divided at the point selected.*

If no contraindication to primary anastomosis is present, intestinal continuity is restored by one of three methods—an end-to-end suture of the terminal ileum and proximal transverse colon, anastomosis of the end of the terminal ileum to the side of the transverse colon or side-to-side anastomosis between the distal ileum and proximal transverse colon. My own preference is for an end-to-end anastomosis of the terminal ileum and transverse colon because of the fact that it eliminates any blind pouch and the integrity of the anastomosis is dependent upon but one suture line. We have encountered no difficulty because of disparity in size between the lumen of the small bowel and the colon. The colon is rarely dilated distal to the lesion and the small bowel can be divided obliquely so that very little disparity in size will remain, and this can be taken into consideration as the sutures are placed. If an end-of-ileum to side-of-colon anastomosis is decided upon, the divided end of the transverse colon is first carefully inverted by one or two rows of catgut sutures reinforced by interrupted silk sutures. If a side-to-side anastomosis is to be carried out, the divided end of the ileum is likewise inverted. If the bowel is well prepared beforehand, we have seen no increase in morbidity or mortality by carrying out an open anastomosis rather than the so-called aseptic type of anastomosis. We feel that the open anastomosis has a definite advantage in that the sutures can be more accurately placed, and that there is less risk of overinversion of the bowel with narrowing of the lumen. It is difficult not only to obtain accurate approximation of the mucosa layer but also to be certain that the sutures catch the tough and important submucosa layer when the anastomosis is carried out over clamps as in the aseptic type of anastomosis.

The bowel may be divided between Oschner clamps with the cautery. I prefer to use a crushing clamp only on the segment of bowel to be resected and to divide the bowel with a knife. This avoids impairing the viability of any of the tissue cells which go to form the actual union by either crushing or heat. A rubber-covered intestinal clamp placed an inch or so from the line of division in the bowel will prevent any serious contamination from the proximal or distal loop. If the bowel has been divided between clamps, an outer posterior row of interrupted silk sutures is first placed, uniting the serosa of the two ends of bowel, and then, with the clamps removed, an inner row of catgut sutures is placed, uniting all coats of the bowel wall. This can be continued anteriorly to form the inner anterior suture line which is later reinforced by

an outer row of interrupted silk sutures. If a running suture is used, care must be taken not to narrow the lumen of the anastomosis, particularly when the end of the ileum is being sutured to the side or end of the colon. Locking the inner posterior row will help to prevent this, but the use of an interrupted suture is definitely better from this point of view. My own preference is for an accurately placed series of interrupted black silk sutures uniting all coats of the bowel wall around the entire circumference. This is then reinforced by a second row of similarly accurately spaced sutures, uniting serosa to serosa.³ This type of anastomosis produces a minimum amount of constriction of the resultant anastomotic stoma and should be associated with a minimal amount of postoperative reaction in the tissues at the site of the anastomosis. The suture line may be reinforced by adjacent epiploic appendages but care must be taken not to interfere with the terminal arterial supply to the bowel which is closely associated with the base of these appendages (Figs. 318 and 319).

The defect in the mesentery is then closed by suture of the peritoneum covering the medial surface of the mesentery by a running catgut suture. Care must be taken not to injure the vessels nourishing the site of the anastomosis. The final step in the operative procedure is to reperitonealize carefully the right lumbar gutter. We believe this is of definite value in decreasing the morbidity associated with resection of carcinoma of the colon. Penicillin, 100,000 units, is placed in the peritoneal cavity, and the wound is closed in layers.

Carcinoma of the Transverse Colon.—The same anesthesia is used as for malignant disease of the right colon and an upper right or left rectus or paramedian incision is used, depending upon the location of the lesion.

If the transverse colon is redundant and the malignancy very close to the center of the colon, it may be possible to carry out a radical resection without additional mobilization. Usually, however, either the hepatic or splenic flexure, and possibly both, will need to be mobilized to secure adequate margins of bowel on either side of the lesion and approximation of the divided ends without tension. The great omentum should be removed with the lesion, and the resection should extend down close to the origin of the middle colic artery from the superior mesenteric artery.

Provided no contraindication is present, intestinal continuity is then restored by an end-to-end approximation of the remaining colon by two rows of silk or silk and catgut suture. The rent in the mesentery is then closed. If either the hepatic or splenic flexure has been mobilized, the denuded area is reperitonealized. Penicillin is left in the peritoneal cavity and the wound closed in layers.

Carcinoma of the Splenic Flexure and Descending Colon.—With the same anesthesia the peritoneal cavity is opened through a left rectus or a left paramedian incision. With the small bowel retracted to the right, the distal transverse colon and sigmoid colon are placed on tension, the lateral peritoneal reflection of the descending colon and splenic flexure is divided and the colon mobilized just as is done on the right side for

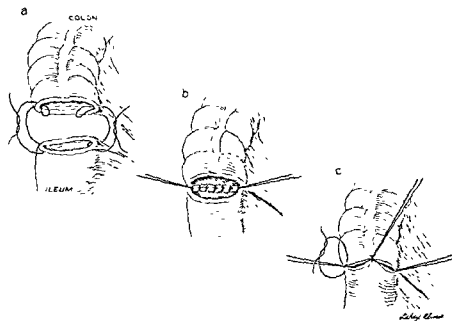


Fig. 318—*a*, If the anastomosis is being carried out without the use of crushing clamps, soiling can be guarded against by a rubber-covered clamp placed 1 to 2 inches from the cut margin of each segment of bowel. The serous and mesenteric borders are approximated by inverting Connell sutures which are cut long and serve as guide sutures.

b, The anastomosis is begun with a posterior row of accurately spaced interrupted sutures, including all coats of the bowel wall. These sutures may be silk or catgut.

c, A similar row of through and-through sutures unites the margins of the bowel anteriorly. This first row of sutures is then reinforced by an accurately spaced row of Lembert or Cushing mattress silk sutures, uniting serosa to serosa. The guide sutures are then reversed and a second row placed posteriorly. Care must be taken not to invert too much of the bowel margin and, if a continuous suture is used for the inner suture line, a purse-string effect must be guarded against.

lesions of the right colon. The left ureter should be identified and carefully reflected posteriorly and the dissection carried medialward until the origin of the mesentery from the posterior abdominal wall is reached. This will expose the jejunum at the ligament of Treitz in the upper end of the incision. The peritoneum over the medial surface of the mesentery is divided carrying it from a point well beyond the lesion down to the origin of the left colic artery from the inferior mesenteric artery and up

to a point on the transverse colon well proximal to the lesion. If the lesion is in the splenic flexure, the left branch of the middle colic should also be divided close to its origin from the main middle colic artery. If the lesion is in the lower descending colon, the first sigmoidal branches of the inferior mesenteric artery should be divided close to their origin. The proximal segment of transverse colon nourished by the right branch of the middle colic artery and the sigmoid colon nourished by the sigmoidal branches of the inferior mesenteric artery are then approximated

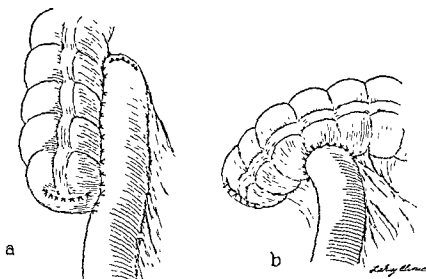


Fig 319.—If one prefers not to carry out an end-to-end anastomosis between the terminal ileum and transverse colon, intestinal continuity may be restored by a careful two-layer closure of the end of the colon and ileum, and an ample side-to-side anastomosis made, as shown in *a*. This anastomosis is usually made by an inner continuous catgut suture reinforced by interrupted silk sutures anteriorly and posteriorly.

b, The cut end of the transverse colon may be inverted and the end of the divided ileum implanted into the side of the colon as shown. Here, as in end-to-end anastomosis, care must be taken not to constrict the stoma by over-inversion or by a purse-string effect at the suture line.

by end-to-end anastomosis. The mesenteric defect is closed and the left lumbar gutter and splenic flexure regions reperitonealized. Penicillin, 100,000 units, is placed in the peritoneal cavity and the wound is closed.

Carcinoma of the Sigmoid.—The lumen of the colon is smallest in the sigmoidal region and constricting lesions with obstruction are common. For these reasons a modified Mikulicz procedure should be seriously considered in any malignancy of the sigmoid associated with obstruction and hypertrophy of the proximal colon. If conditions will permit a primary end-to-end anastomosis following resection, one must be particularly careful not to overinvert the margins of the bowel at the line of suture so that early or late obstruction may occur.

A left mid rectus or paramedian incision is used. The sigmoid colon is mobilized medialward to the root of the mesentery. If the lesion is high in the sigmoid it will usually be necessary to mobilize the descending colon and splenic flexure to permit the resection of an adequate margin of bowel proximal to the lesion and the restoration of intestinal continuity without tension on the suture line. The left ureter must be visualized and preserved as this dissection is carried medialward. The sigmoidal arteries should be divided close to their origin from the inferior mesenteric artery, and the terminal branch of the inferior mesenteric, the superior hemorrhoidal artery, preserved for nourishment of the rectosigmoid.

If, because of the position of the growth, an adequate cancer operation cannot be done without division and removal of the trunk of the inferior mesenteric artery along with its terminal superior hemorrhoidal branch and accompanying lymph nodes, an abdominoperineal resection or wide anterior resection will give that patient his best chance for cure

POSTOPERATIVE CARE

The Miller-Abbott tube in patients with carcinoma of the right colon or the Levin tube in patients with carcinoma of the left colon is placed on suction and the former is usually not removed until the patient has passed gas by rectum. During this time the electrolytic and caloric requirements are supplied by intravenous administration. The penicillin level is maintained by one injection of 300,000 units per twenty-four hours. The rectal tube is inserted at intervals to decompress the distal segment.

Leg and foot exercises to diminish venous stasis in the legs and regular, deep breathing exercises to prevent atelectasis are emphasized during the early postoperative period.

CONCLUSIONS

A one-stage resection for carcinoma of the colon with primary anastomosis with its greatly decreased hospitalization period is the procedure of choice for uncomplicated cases of malignant disease of the large bowel. With adequate preoperative preparation of the patient, accurate anastomosis, and the use of a proximal diversion colostomy or a two-stage Mikulicz type of procedure in patients with obstruction or other complication, this procedure will be associated with a mortality rate that will compare favorably with that of the more conservative types of operative procedures for resection of carcinoma of the colon.

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EXCISION OF CYSTS OF BARTHOLIN'S GLAND

RICHARD B. CATTELL

All too frequently the removal of a Bartholin cyst results in an irritating experience to the surgeon because of profuse bleeding that may be encountered, as well as a long period of discomfort for the patient. Too little attention is paid to some of the minor technical procedures employed for conditions affecting the external genitalia and anus when, by special attention to such problems, they can be done with a minimum of difficulty and disability. The incidence of cyst of Bartholin's gland seems to be decreasing with earlier and better treatment of genital infection, notably improved by the use of penicillin. These cysts should be excised at a time of election when no infection is present. They may disappear spontaneously but usually recur and should be removed at a time when the cyst is distended; otherwise operation may be unsuccessful because of incomplete excision.

If infection is present it will frequently subside without operation with the aid of hot douches and hot sitz baths. If infection does not subside promptly, or if undue discomfort is present, incision and drainage, as an office procedure, utilizing procaine local anesthesia, will result in relief of symptoms and subsidence of infection. The use of packs at the time of incision and drainage should be discouraged, since they result in excessive scarring and make the subsequent excision more difficult.

The incision for excision of the cyst is made directly over it in the longitudinal axis of the vulva (Fig. 320, *a*) and we prefer to make it on the cutaneous side. Te Linde prefers an incision through the mucosa in the region of the duct opening. When there have been repeated attacks of inflammation of a cyst, this may be preferred because of the difficulty of dissecting the thin, fragile mucosa from the cyst. In most cases, with the cutaneous incision, the cyst may be dissected up by sharp dissection (Fig. 320, *b*) with facility since the gland opening is closed. The mucous membranes may be freed medially without buttonholing the thin membrane. Bleeding is profuse but can be controlled with fine hemostats which need not be ligated by the technic that is described.

At times the cyst may be opened and it can then be dissected, as suggested by Curtis, similar to a hydrocele sac, making certain to remove all of the cyst lining.

The chief point in the technic that we employ is the control of bleeding and elimination of dead space. After removal of the cyst, a continuous, fine chromic suture with an atraumatic needle is used to effect the closure (Fig. 320, *c*). The single suture obliterates the depth of the wound and

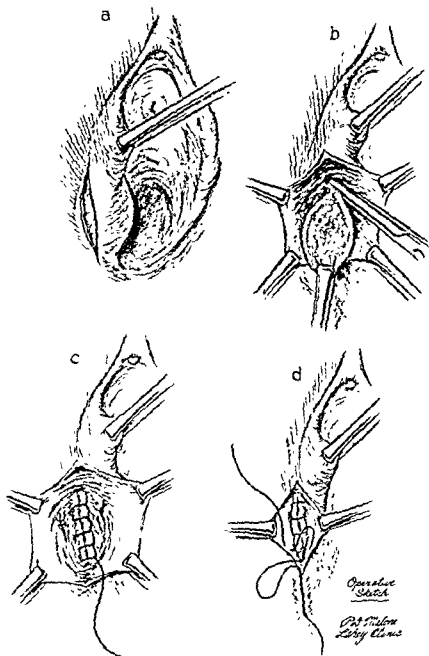


Fig 320 —Removal of a cyst of Bartholin's gland

a, Vertical cutaneous incision directly over the cyst

b, The cyst has been dissected free, taking care to avoid penetration of the mucosa on the medial side. The venous plexus and veins are temporarily clamped

approximates the sides of the cavity by passing it back and forth three times, and the same material is used for closure of the skin as a subcuticular suture (Fig. 320, d).

This type of closure results in a minimum of reaction in the wound and avoids hemorrhage, with a minimum of swelling. Healing is quite rapid and the patient may be discharged from the hospital within one or two days. Twenty-four hours after operation, hot sitz baths may be taken twice a day. The incisional scar is soft and pliable, with little thickening, and does not remain sensitive or painful for any appreciable period. It results in a minimum of discomfort and disability for the patient.

may permit a procedure which one would otherwise hesitate to use. In the older age group the problem of child-bearing no longer applies and dyspareunia becomes less important. One learns by experience, however, never to disregard entirely the complication of dyspareunia in any patient, regardless of age. Beyond middle age the possibility of malignant disease of the cervix or fundus may influence the choice of operative procedure, and here also the general health of the patient often must be taken into consideration.

Degree of Prolapse.—Moderate degrees of prolapse can be well controlled by procedures such as the Manchester-Fothergill operation in which the cervix is amputated and the cardinal ligaments approximated in front of the lower uterine segment. This is particularly true when the major part of the prolapse is due to a markedly elongated cervix. We do not believe, however, that it is reasonable to expect such a procedure to control a complete prolapse in which all, or practically all, of the uterus can be drawn outside the introitus. Nor do we feel that the Watkins-Wertheim interposition procedure is suitable for prolapse of this degree. Here, the fundus may be held up well by its suspension to the tissues along the pubic rami, but unless some additional fixation is used, the lower uterine segment will swing down and prolapse. Vaginal hysterectomy will provide the most satisfactory fixation for this severe degree of prolapse and unless contraindicated by other considerations, is the procedure of choice in these patients.

Degree of Cystocele Present.—The size of the cystocele associated with uterine prolapse will vary markedly from patient to patient. There may be little or no cystocele present in the rare nulliparous patient in whom uterine prolapse develops or it may, in other patients, represent the major part of the pelvic descent. If the age of the patient and the size of the uterus do not offer contraindications, few procedures are better adapted to the treatment of a large cystocele associated with moderate prolapse than is the Watkins-Wertheim interposition operation. On the other hand, if the cystocele as well as the prolapse is only moderate and the patient is in the premenopausal age, a procedure of the Manchester-Fothergill type will correct the prolapse just as satisfactorily and will provide a more pliable and better functioning vagina.

Size and Condition of the Uterine Fundus and Cervix.—The presence of uterine bleeding, or a Papanicolaou smear suggestive of malignant disease, may make it desirable to remove the uterus in a patient with uterine prolapse. A small uterine fundus is not well adapted to support a large cystocele when the interposition operation is considered. A fibroid uterus of considerable size may make vaginal hysterectomy unduly hazardous and the interposition procedure unsatisfactory.

Presence of Other Pathologic Conditions in the Pelvis.—Pelvic ad-

hesions as a result of previous pelvic surgery or from pelvic inflammatory disease should make one hesitate before attempting vaginal hysterectomy or the interposition procedure in the treatment of uterine prolapse. Unless there is a definite indication for removing the fundus or unless the prolapse is of marked degree (not likely), a Manchester-Fothergill procedure is preferable under these circumstances.

Vaginal Prolapse following Hysterectomy.—This unfortunate development, which is still occasionally encountered, should occur less frequently as the importance of the proper suspension of the vaginal vault at the time of hysterectomy becomes better appreciated. On the other hand, if the necessity of carefully suspending the vaginal vault by the cardinal ligaments, uterosacral ligaments and the parametrial tissue surrounding the uterine artery, is not fully appreciated, the trend from supravaginal hysterectomy toward total hysterectomy may well result in an increased incidence of this serious complication.

Careful examination of these patients may reveal that the vaginal prolapse is largely due to a cystocele or rectocele, with a lacerated perineum which was not corrected at the time of the hysterectomy. If the vaginal vault is reasonably well suspended a careful anteroposterior repair may correct the situation. Occasionally, the cystocele and rectocele may be associated with prolapse of an elongated cervical stump. This situation may be corrected satisfactorily by removing most of the cervix and approximating the cardinal ligaments in front of the remaining segment of cervix and utilizing this as a support for the vaginal vault. At other times it will be more satisfactory to interpose the remaining segment of cervix beneath the bladder, as in the Watkins-Wertheim interposition procedure, following amputation of any redundant portion, and using this as the main support of the vaginal vault. When the cervix is small and atrophic, or has been entirely removed along with the uterus, a more serious problem is presented. In the elderly patient in whom the function of the vagina is not important, a partial (Le Fort) or total colpocleisis may be carried out and will usually correct the condition quite satisfactorily. In the younger patients in whom it is important to preserve the function of the vagina, some type of abdominal fixation of the vagina must be carried out. The vaginal vault may be suspended to the anterior abdominal wall by silk sutures (Brady) or by fascial strips if its length is not sufficient to reach the anterior abdominal wall (Ward) or by suspension to the uterosacral ligaments according to the vaginal method described by Miller.

OPERATIVE PROCEDURES

Vaginal Repair with Abdominal Suspension.—*Advantages.*—This procedure is most frequently used in young women with symptomatic

uterine prolapse, cystocele, rectocele and lacerated perineum who desire to have more children. If symptoms are not marked I usually advise these young women to wait until they are past the child-bearing period

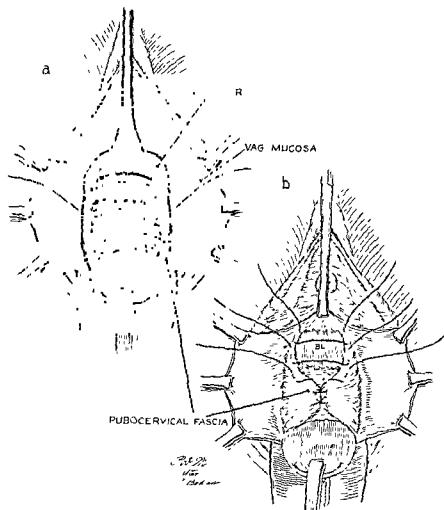


Fig 321 —a, Inverted T incision has been made in the anterior vaginal mucosa and the mucosa reflected on each side, carrying it up to within 1 cm. of the urethral orifice. A small transverse incision has been made on each side at the upper end of this T incision to prevent tearing into the urethral orifice. The bladder has been mobilized from the anterior surface of the cervix and uterus. b, Pubocervical fascia is approximated by mattress sutures beneath the bladder and the urethra. If the patient has urinary incontinence, particular care must be given to approximation of the fascia beneath the urethra and the bladder neck.

and then have a definitive repair carried out. Occasionally, these patients may be carried along by the use of a pessary until they have completed their family.

Disadvantages.—Cystocele, rectocele and lacerated perineum can be

corrected quite satisfactorily but, since nothing is done to the uterus itself from below, dependence must be placed upon the round ligament suspension to correct the prolapse. Suspension by the round ligament from above is never as dependable as when the far more important supporting structures in the base of the broad ligament are used, as in the vaginal operations for uterine prolapse. Ventral fixation of the uterus itself is out of the question since the main purpose of the abdominal part of the procedure is to correct the prolapse and at the same time permit subsequent pregnancy.

Technic.—1. An anterior colporrhaphy is first carried out, approximating the strong pubocervical fascia beneath the bladder from the urethra to the cervix (Fig. 321).

If stress incontinence is present, particular attention must be given at the time of the vaginal repair to correction of the urethrocele and to approximation of the musculofascial tissues about the bladder neck.

2. Careful approximation of the levator ani muscles and repair of the perineum are essential parts of any operative procedure for uterine prolapse (Fig. 322), and it is important to emphasize that this vaginal part of the procedure should be carefully carried out if a satisfactory result is to be obtained by this combined procedure.

3. As in all operations for prolapse, one must make certain that an enterocele is not present. If an enterocele is present and is not corrected it may necessitate reoperation in spite of an otherwise excellent vaginal repair. If it is present the sac should be dissected free and amputated as in any other type of hernia repair. The defect is then closed by approximation of the uterosacral ligaments behind the cervix. The closure of the defect can be reinforced by plicating sutures above when the suspension part of the procedure is carried out.

4. My preference for the round ligament suspension part of the operation is the use of a modified Gilliam suspension in which the round ligaments are withdrawn through the internal inguinal ring on each side and brought out over the rectus muscle to be sutured to the under-surface of the rectus fascia. The point of emergence of the round ligaments at the internal inguinal ring should be checked to make certain that no aperture remains through which small bowel might prolapse. Shortening of the uterosacral ligaments will also help to maintain the uterus at the proper level.

The Manchester-Fothergill Procedure. Advantages.—This is one of the most widely applicable operative procedures for the correction of uterine prolapse. It is not incompatible with pregnancy and normal delivery although the incidence of sterility, premature delivery and cervical dystocia is somewhat increased following its performance. It does not shorten the vagina and, if properly carried out, does not pro-

duce dyspareunia. The peritoneal cavity is not opened and this procedure probably involves less operative risk than any other type of operation for uterine prolapse. It will correct satisfactorily all but third degree or complete prolapse and the most important supporting structures of the uterus, namely the parametrial tissue surrounding the lower uterine segments (cardinal ligaments), are utilized for the support of the uterus.

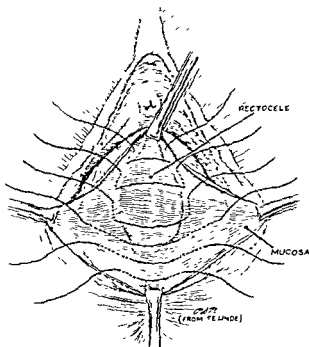


Fig 322 —A transverse incision has been made at the mucocutaneous border and the vaginal mucosa of the posterior vaginal wall elevated. If a rectocele is present, as shown, it is reduced by carefully approximating the perirectal fascia with mattress sutures. The levator and transversus perinei muscles are then approximated from within outward. Care must be taken to restore the normal contour of the vagina and avoid the production of a ridge, either up in the vagina at the height of the repair or at the fourchet (dashboard perineum).

Any existing or potential disease of the cervix is eliminated and, should uterine bleeding subsequently occur, the uterine cavity can be curetted without difficulty.

Disadvantages —If one must operate for a uterine prolapse in a young woman in the child-bearing period, the relative sterility and possible dystocia associated with this operation must be kept in mind. We also feel that this procedure does not give sufficient support in patients with third degree or complete prolapse of the uterus. When the prolapse is associated with third degree retroversion it is usually not possible to correct the retroversion by this operation.

Technic.—1. Following dilatation and curettage, an inverted T-shaped incision is made in the mucosa of the anterior vaginal wall. The mucosa is reflected, the bladder mobilized up from the cervix, and approxima-

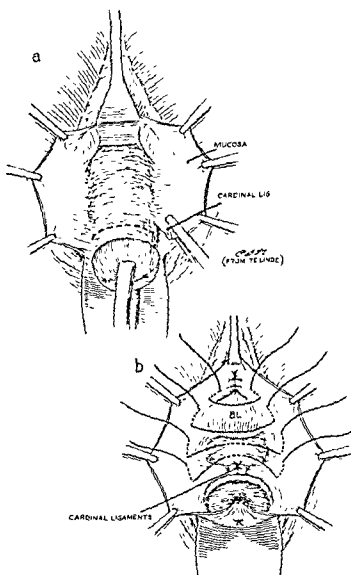


Fig. 323.—*a*, The anterior vaginal mucosa has been reflected and the cardinal ligament is clamped, divided and ligated on each side *b*, The bladder has been mobilized up from the cervix and anterior surface of the uterus. The pubocervical fascia is being approximated with mattress sutures, the cardinal ligaments have been approximated in front of the lower uterine segment and the cervix amputated. Closure of the vaginal mucosa is begun with Sturmdorf suture, uniting it to the uterine canal in the posterior midline.

tion of the pubocervical fascia beneath the bladder carried out by interrupted mattress sutures of fine chromic catgut. If there is a history of stress incontinence, care must be directed particularly to the urethral floor and the bladder neck.

2. The mucosa is then reflected from the posterior surface of the cervix, the cervix is amputated and the base of each ligament as it inserts into the lower uterine segment is clamped, divided and ligated (Fig. 323, a).

3 This fibromuscular tissue (cardinal ligament) is then approximated anterior to the new cervix above the line of amputation (Fig. 323, b). This is the essential point in this operative procedure and this strong fibromuscular tissue can be approximated as far as is necessary to raise the new cervix well up in the pelvis and thus provide a high firm support for the vaginal vault. The operation is completed by approximating the

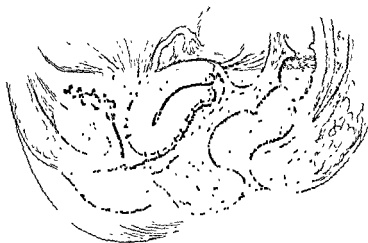


Fig 324 — Watkins-Wertheim interposition operation The uterus has been delivered and the cornu sutured to the fascia along the pubic rami on each side The bladder now rests upon the posterior surface of the fundus of the uterus The vaginal mucosa is closed over the anterior surface and the lower uterine segment following amputation of the cervix This provides a firm support for the anterior vaginal wall

anterior vaginal mucosa, repair of the rectocele, if present, and finally, repair of the perineum

Watkins-Wertheim Interposition Operation.—*Advantages.*—If the patient has a large cystocele, a moderate degree of uterine prolapse and a normal-sized uterus, the interposition of the uterine fundus beneath the bladder will provide as secure a support for the cystocele as can be found (Fig. 324). Although the peritoneal cavity is opened, this procedure does not involve extensive dissection and can be carried out with a minimum of operative risk. Any existing disease of the cervix can be eliminated by adding cervical amputation, and this also permits a higher support of the lower uterine segments.

Disadvantages.—The Watkins-Wertheim interposition operation is incompatible with pregnancy and if carried out in the child-bearing age

the fallopian tubes must be ligated. Because of the firm, unyielding anterior vaginal wall, dyspareunia is a complication which must be considered in young or middle-aged women. If the degree of prolapse is marked, suspension of the uterine fundus beneath the rami of the pubis does not control prolapse of the lower uterine segment and cervix. If cervical amputation is added, the procedure will correct second degree prolapse but complete prolapse is still, in our opinion, better treated by vaginal hysterectomy. If the uterine fundus is small and atrophic it does not offer a satisfactory support for the bladder. If the fundus is the seat of a small uterine fibroid, it may not be possible to interpose it beneath the bladder and preserve a satisfactory vagina. If subsequent uterine bleeding occurs, the fundus is in a difficult position to curet satisfactorily in order to rule out the presence of endometrial carcinoma.

Technic.—1. Following dilatation and curettage, the mucosa of the anterior vaginal wall is reflected, the bladder mobilized and advanced from the cervix to a point where the vesical uterine fold is encountered and the peritoneal cavity opened. The bladder must be completely mobilized so that it will rest freely on the posterior surface of the uterus which is to be interposed beneath it. The dysuria and other urinary symptoms which have been reported following the employment of this procedure are probably due to an inadequately mobilized bladder, the floor of which is pushed up by the interposed uterine fundus.

2. The adnexa are then carefully palpated to rule out adnexal disease and the presence of any intra-abdominal fixation of the fundus. The size of the uterus can also be determined at this point, and it can be determined whether it can be brought beneath the bladder to form a satisfactory support.

3. The cervix is then amputated following ligation of the cervical branches of the uterine arteries and the posterior vaginal mucosa approximated to the cervical canal by a Sturmdorf suture.

4. The uterine fundus is then delivered through the opening in the vesico-uterine fold of peritoneum. This can be done either by a tenaculum or by successive figure-of-eight sutures in the anterior wall of the uterus. Each cornu is then securely sutured to the firm fibromuscular suture along the lower border of each ramus of the pubis. The mucosa is approximated over the fundus of the uterus and the anterior portion of the cervix and repair of the perineum is carried out (Fig. 325).

Vaginal Hysterectomy.—*Advantages.*—Vaginal hysterectomy is, in our opinion, the most satisfactory method of treating the patient of 60 years of age or over who has severe or complete prolapse of the uterus. Although it involves more dissection than either the Manchester procedure or the interposition operation, it still can be carried out with a low operative risk, even in elderly women. The utilization of all the

supporting structures contained in the broad ligaments, as well as the uterosacral ligaments, insures a secure, adequate support to the vaginal vault. If necessary, these broad ligaments can be approximated to form a sling and fixed to the pubic rami beneath the bladder. The fundus as well as the cervix is eliminated, which is advantageous in this group of patients who all fall in the cancer age group.

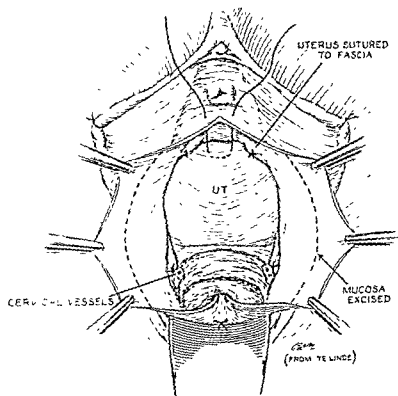


Fig 325.—The cervical branches of the uterine artery have been divided and ligated. The cervix has been amputated and the mucosa approximated to the uterine canal in the posterior midline. The cornu of the uterus has been sutured to the fascia along the pubic rami on each side and the mucosa of the anterior vaginal wall will now be approximated in the midline to the uterus after excision of the redundant portion.

Disadvantages.—When we employ vaginal hysterectomy for the correction of uterine prolapse, utilizing the approximated broad ligaments for suspension of the apex of the vaginal vault, there is likely to be appreciable shortening of the vagina. For this reason we do not feel that it is the procedure of choice in patients in whom the function of the vagina is important unless the prolapse is complete. Pelvic adhesions,

is a series of other operations which it is not sufficient to describe, but which consist of the steps from which almost all operations of this combination are constructed. Immediately after opening the peritoneum from below the right hand is placed at the point of the incision, and the peritoneum from which will connect the cutaneous incision to the abdominal opening is then raised, the proper vessels are exposed, and a series of further surgical methods of treating the disease applied.

Second.—The lungs will completely replace within six months the whole thoracic contents and their removal is the easiest surgical method. There consists chiefly in cutting the bronchial vessels from the lungs, and then proceeding to cut across the pulmonary and proper the respective great vessels as a routine.

3. Division and removal of vessels up to the first bifurcation of the bronchus for the purpose of the lungs is found to cause no injury in the animal. Immediately after the vessels and pulmonary arteries have been cut, there are no signs of actual suppuration. The vessels are reflected from the anterior surface of the lungs, the surface being cut, the pulmonary vessels exposed. The pulmonary artery is cut on the right side in the dissection procedure. Following which the lungs are reflected from the posterior surface of the chest and the peritoneum opened in the posterior angle. The lungs are delivered from the anterior surface and both were and lungs were to the animal's eyes and then passed upwards and visualization of the entire left hand lumen. The hand lumen is then fixed by two wire sutures, and the attachments to the chest and other organs were to be cut, proceeding for removal of tubercular disease the division can be carried out up close to the lungs and thus avoid the risk of infecting the cavity.

4. With the chest—The chest cavity is opened in the opposite direction, the chest wall lumen is divided and divided in a similar manner and the lungs and other removed.

5. The ribs and sternum are then removed and removed if necessary.

6. The peritoneal cavity is closed by suturing the anterior and posterior margins of the peritoneum, thus creating a smooth peritoneal floor and the lower breast lumen becomes incorporated at one end of the lower Fig. 250.

7. The thoracic cavity is approximated beneath the arches and diaphragm and the upper end of the breast lumen approximated in the middle beneath the new peritoneal floor.

8. The interior border of each breast lumen may then be sutured to the chest wall, thus giving rise to the proper shape of the breast lumen. The hand lumen is then closed. The anterior thoracic cavity

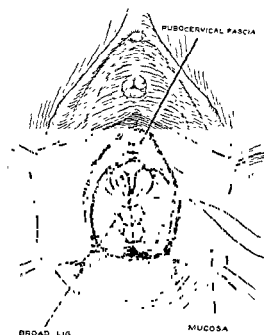


Fig 326 —Vaginal hysterectomy The uterus has been removed The anterior and posterior peritoneal flaps have been approximated and now the ligated broad ligaments on each side are approximated in the midline to form an extraperitoneal sling which will support the vagina



Fig 327 —The vaginal mucosa has been reflected from the underlying fascia both anteriorly and posteriorly This prolapse of the vagina is then inverted by successive purse-string sutures until it is entirely replaced The excess mucosa is excised, leaving just enough to cover the last inverting suture

cosa is closed, utilizing the broad ligament sling as a support to the anterior wall and the vaginal vault.

8. The posterior vaginal mucosa is raised, carrying the dissection almost to the height of the anterior dissection.

9. The levator ani muscles are then visualized and approximated as high as possible, the height of the approximation being governed by the need of that particular patient for preserving a functioning vagina. The transverse perineal muscles of the perineum are then built up to form additional support for the anterior wall.

10. A sponge is placed in the vagina for hemostasis, and an indwelling catheter is left in the bladder as in all other vaginal plastic procedures.

Total Colpocleisis.—*Advantages.*—This procedure will correct prolapse of the vaginal vault with associated prolapse of the bladder and rectum, following supravaginal or total hysterectomy. It can usually be carried out without undue operative risk, even in elderly patients.

Disadvantages.—The importance of complete loss of vaginal function will vary according to the age, marital status and personality of the patient.

Technic.—In total colpocleisis the entire vaginal mucosa from the anterior and posterior walls is removed and the vaginal vault inverted by successive purse-string sutures (Fig. 327), or successive rows of interrupted sutures approximating the anterior and posterior submucosal fascial structures. The small margin of the mucosa at the introitus is then approximated with a few interrupted sutures.

Combined Procedures.—As has been pointed out before, salient features of one or more of the previously mentioned procedures may be combined to fit a particular need in a particular patient. We have had no experience with the Spalding-Richardson composite operation as described by Te Linde but the underlying principles are sound and it should give excellent results when indicated. It eliminates both the fundus and the cervix as a source of future trouble for the patient and at the same time preserves the lower uterine segment with its undisturbed important adjacent fascial structures to form the support for the vaginal vault.

CONCLUSIONS

As has been pointed out before, a well chosen technic carried out with a minimum of trauma to the patient, with careful dissection and accurate approximation of tissue and the use of fine suture material, will pay high dividends in grateful, comfortable patients and should result in a minimum of recurrences in uterine prolapse.

contains afferent neurons. However, since excision of the superior hypogastric plexus in many instances relieves pelvic pain, it must be assumed that visceral afferent fibers are associated with the sympathetic nerves and that these fibers are capable of transmitting pain impulses to the central nervous system from pelvic visceral receptors.

Apparently division of the presacral nerve does not appreciably alter any normal physiology of the pelvic organs. Fontaine and Herrmann stated that section of the superior hypogastric plexus does not alter the normal menstrual cycle, does not interfere with spontaneous parturition, does not produce glandular atrophy, chronic pelvic congestion or any disturbances of motor function of the bladder or rectum. Meigs noted minor changes in the menstrual cycle following presacral neurectomy.

SELECTION OF CASES

It is not the purpose of this paper to discuss types of dysmenorrhea and indications for presacral neurectomy. Our indications for presacral neurectomy have been described by Marshall and Kennedy (1945). Suffice it to say that patients with dysmenorrhea should be carefully selected. They should have complete study and thorough trial with conservative medical measures before the patients are subjected to this procedure. Although Haman showed that patients with dysmenorrhea have a lower pain threshold than normal women it must be remembered that dysmenorrhea is a symptom and not a disease—that presacral neurectomy is symptomatic treatment and not a form of therapy dealing directly with the cause of the symptom.

ASSOCIATED PELVIC DISEASE

All abnormalities of the pelvic organs encountered during presacral neurectomy should be treated by corrective surgery. In cases of cervical stenosis an adequate dilatation or curettage should be performed. When ovarian tumors or cysts are found, partial oophorectomy and excision of cysts are indicated. Endometriosis is searched for and when found, especially in young individuals, is treated conservatively by cauterization of implants. Retroverted uteri are suspended. The appendix is removed routinely. Phaneuf pointed out that pain occasioned by mechanical disturbance of the appendix, such as that accompanying a retrocecal appendix or frequently from an appendix which is adherent to the pelvic organs, may increase at the time of menstruation.

PROCEDURE

Presacral neurectomy is performed most often at this clinic under spinal anesthesia. A dilatation and curettage precedes the laparotomy

The patient is then placed in the Trendelenburg position and the abdominal cavity is entered through a lower midline incision extending from the umbilicus to the symphysis. A careful exploration is performed

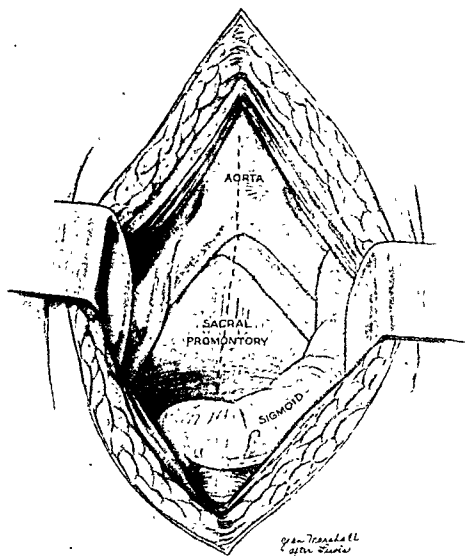


Fig. 328 —Incision of posterior peritoneum.

All pelvic abnormalities are noted and any corrective surgical procedures that are indicated, especially the removal of a large tumor which may interfere with exposure, may be dealt with at this time. The intestine is packed above so that the promontory of the sacrum, the bifurcation of the aorta, and the iliac vessels are well exposed. The sigmoid may be

redundant and extend to the midline, in which case it should be mobilized and retracted laterally. If the patient is thin, the presacral nerve

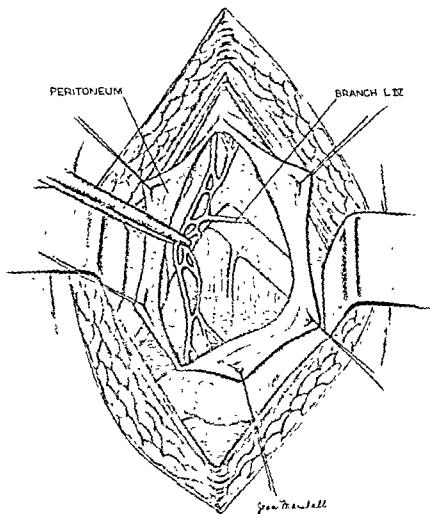


Fig 329 —Exposure of plexus

may be seen and palpated beneath the posterior parietal peritoneum. In obese patients, however, it may be hidden in fatty tissue.

The posterior parietal peritoneum is divided in the midline from just above the bifurcation of the aorta down to the level of the bifurcation

sutures. The triangle formed by the bifurcation of the aorta and the common iliac arteries is then well exposed. The left common iliac vein is seen medial to the left common iliac artery. The right common iliac vein is not visualized as it runs lateral to the right common iliac artery outside the field of dissection. The right ureter is usually exposed, the left ureter is rarely exposed. The midsacral artery parallels the presacral nerve and occasionally is divided to facilitate freeing the plexus.

A tape is placed around the plexus and the adjacent closely attached areolar tissue so that the plexus may be lifted from its bed, thus making dissection easier (Fig. 329). The dissection must be meticulous and hemostatic so that all of the fibers of the plexus and the closely adjacent connective tissue are excised, and so that there is no possible chance of injuring the important neighboring structures. The upper aspect of the plexus is freed to about 2 to 3 cm. above the bifurcation of the aorta and is divided and ligated at this level. The dissection is then continued caudad over the left iliac vein to the bifurcation of the common iliaes. It is well to remember that the fibers from the upper ganglions may pass posterior as well as anterior to the iliac vessels.

As the lower aspects of the plexus are approached it may be found to divide into two more or less distinct branches, the so-called hypogastric nerves. At the level of the bifurcation of the common iliaes the plexus is excised and the distal branches ligated. The field is examined for hemostasis and the posterior peritoneum closed. If indicated corrective procedures have not been performed earlier, they should be carried out at this time and appendectomy performed. The abdomen is closed in layers.

The operation is a simple procedure with practically no mortality. Postoperative complications are few. Presacral neurectomy, however, is associated with the same hazards and complications of any laparotomy under general anesthesia and because of this it should be elected only after careful thought and deliberation. By proper selection of cases and complete, careful excision of the plexus, gratifying results may be obtained.

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TREATMENT OF HEMORRHOIDS

NEIL W. SWINTON AND JOHN M. SLAUGHTER

In the June numbers of this publication in 1939¹ and 1942² articles were published from this clinic on the treatment of hemorrhoids. In the ten years which have elapsed since these reports, certain refinements have been developed in our management of this condition. We have increased our experience with the injection method of treatment of uncomplicated internal hemorrhoids and are more enthusiastic over its value than we were ten years ago. The plastic amputative type of hemorrhoidectomy has been used less and less in the operative treatment of "piles," and at the present time is reserved almost entirely for those patients with minor degrees of anal prolapse.

The purpose of this presentation is to review briefly the fundamental principles of the injection and operative methods of the treatment of hemorrhoids. Also, a simple type of hemorrhoidectomy will be described which has been employed for a ten year period and has given us satisfactory results.

SELECTION OF CASES

Hemorrhoids are the most common pathologic entity found in the anorectal area. The incidence of this condition is not known but it is generally accepted that at least one-half of those patients coming to a sigmoidoscopic examination will present some degree of hemorrhoids. Many of these patients will, of course, require no treatment, but it has been our policy to advise treatment for those patients with hemorrhoids who complain of symptoms related to them. We have never been impressed with the claim that hemorrhoids or infected crypts without associated symptoms which might conceivably be acting as a focus of infection are of any particular significance. Occasionally patients are encountered with symptomless skin tags or hemorrhoids, who have been advised to undergo rectal surgical procedures because of the potential danger of malignant degeneration. There is no evidence that hemorrhoids or skin tags have any relation to malignant degeneration.

The common symptoms associated with hemorrhoids are bleeding, pain, protrusion and itching or pruritus.

Rectal bleeding is one of the most important problems with which we have to deal and it is one of the most common complaints encountered in a large general practice. Every physician, internist as well as surgeon, must have a thorough understanding of the relation of rectal bleeding. Patients today are cancer-conscious. There has been so much pub-

licity in the lay press concerning the possible relation of bleeding from any of the body orifices to malignancy that the majority of patients whom we see at the present time with rectal bleeding are aware of the possible relation of such bleeding to cancer. In spite of this, patients are still seen with rectal bleeding and advanced malignant disease of the colon and rectum who have undergone a hemorrhoidectomy within six months' time of their visit to the clinic. It is our impression at present that the greatest number of errors in the delay in the detection of malignant disease of the colon and rectum is caused by inadequate examinations on the part of physicians rather than by any delay in the patient's reporting the presence of rectal bleeding to his doctor.

A spot of blood noted on the toilet tissue probably arises from a fissure, anal pruritus or a skin tag. The painless spurts of blood noted in the toilet which precede or accompany a bowel movement are ordinarily caused by internal hemorrhoids. The only safe policy to follow in the presence of any type of rectal bleeding, however, is to assume that malignancy may be present and to carry out complete rectal and colon studies which will rule out any such possibility. These examinations should consist of the following and be performed in the order named: an inspection of the anal orifice and perianal tissues; digital palpation and anoscopic visualization of the anal canal, and sigmoidoscopic examination of the terminal 10 inches of the gastrointestinal tract. Roentgenographic studies of the remaining colon should be made in addition whenever indicated.

The majority of patients with hemorrhoids which have been present for some time and which are large will usually complain of some degree of pain or discomfort in the rectum. The elicitation of this fact in the history is particularly important in determining the type of treatment to be followed as it has been our experience that a complaint of pain or the presence of pain on examination usually contraindicates the injection method of treatment.

The presence of pain in the history or at the time of examination usually indicates the presence of thrombi, prolapse, infection, cryptitis, stenosis or fissure accompanying the hemorrhoids. Hemorrhoids associated with any of these conditions require surgical excision and are not suitable for the injection method of treatment.

Ideal candidates for the injection method are usually those patients who have painless rectal bleeding.

Varying amounts of protrusion from the anal canal will commonly be found associated with hemorrhoids. It is important to determine the extent of this protrusion in each patient. Minor degrees may be controlled with injections but the more extensive degrees of protrusion require surgical excision. At the clinic, sigmoidoscopic examinations are

usually performed with the patient in an inverted position. This position is not satisfactory for the determination of prolapse or protrusion of hemorrhoids. It is our custom when a sigmoidoscopic examination has been completed with the patient in an inverted position to have him assume a second position either on his side or squatting so that a digital examination and anoscopic visualization of the anal canal may be performed and the degree of prolapse or protrusion accurately evaluated. At the time of operation when the patient is under anesthesia and in a prone position, this may be demonstrated by inserting a plug of dry gauze in the anal canal and gently withdrawing the gauze.

Anal pruritus or itching is commonly associated with hemorrhoids. This pruritus results more from the perianal dermatitis and constitutional background of the patient than from the "piles" themselves. It is a common experience to examine a patient with a long-standing history of anal pruritus who has had in the past one or more operations for hemorrhoids, without relief. Hemorrhoidectomy in itself rarely permanently relieves the patient with long-standing anal itching. The removal of large, edematous, infected skin tags interfering with mechanical cleansing of the perianal area may be a necessary adjuvant to the constitutional and dermatologic aspects of treatment. Hemorrhoidal injections may at times be of assistance in relieving pruritus, but hemorrhoidectomy in itself is usually a minor part of the treatment of pruritus ani.

A complete history and physical examination should be carried out on all patients who come for treatment of their hemorrhoids. At the clinic, routine urinalysis, blood Hinton determination and a blood count are ordinarily also done.

It is particularly important to elicit in detail from the patient any gastrointestinal symptoms other than those related to the anorectal area. Bowel dysfunctions such as chronic catharsis, chronic constipation or diarrhea frequently accompany hemorrhoids. All such gastrointestinal disturbances should be carefully considered in the ultimate treatment of the patient.

With the completion of a careful history, a general examination and special examinations of the rectum and colon, the type of treatment for the individual case is usually obvious. Our indications for the injection method of treatment have previously been stated.

INJECTION METHOD

At the present time approximately 30 per cent of those patients receiving treatment for hemorrhoids have injections.

The technic of the injection method of treatment used at the clinic was taken originally from that of Buie, Terrell and others. This technic has been described in detail in our previous articles and has not been

altered Terrell has recently reported on an improved quinine and urea hydrochloride solution with a lowered hydrogen ion concentration (diuride) which has given improved results. We have had no personal experience with this solution to date. The number of patients who may be counted as failures of the injection method of treatment are few. An occasional patient is not relieved of his symptoms. When this occurs it is usually due to faulty judgment in the selection of the injection method of treatment in the first place. The majority of patients are relieved of *their bleeding after the first injection. A few patients return after a period of years with mild recurrences of their hemorrhoids which may be controlled with a second series of injections. Less commonly, a patient returns with recurrence which requires surgical excision.*

The complications of the injection method of treatment are exceedingly rare but, when they do occur, may be serious. In our experience, a pelvic phlebitis has developed in 3 patients following hemorrhoidal injections. Two to three days after the injection the patient has complained of a feeling of pressure and distress in the lower abdomen and rectum. A low grade fever has been present. Rectal examination has revealed *huge indurated masses filling the perirectal spaces and extending up into the pelvis. Fortunately, in each of the 3 patients in our series the inflammatory mass subsided after four to six weeks without abscess formation or permanent sequelae. All complications following the injection method of treatment, however, do not have such a fortunate outcome. During the past six months we have treated 2 patients referred to us following hemorrhoidal injections given elsewhere, who had massive pelvic and rectovaginal abscesses, resulting in rectovaginal fistulas and requiring colostomy. In at least 1 of these 2 patients it is doubtful because of the local destruction of tissue whether the rectovaginal fistula can ever be satisfactorily repaired.*

SURGICAL TREATMENT

For those patients whose hemorrhoids require treatment and are not suitable for the injection method, excision is indicated. Discrete thrombotic hemorrhoids which cause local pain may be excised satisfactorily as an office procedure after the "pile" has been symmetrically distended with a 1 per cent solution of procaine. Many small thrombi do not cause symptoms, however, and will subside without any surgical treatment. Massive thrombi accompanied by edema and prolapse are best treated conservatively until the edema and infection have subsided. Elevation of the hips, massive hot wet dressings and bed rest usually suffice for the relief of the acute symptoms. Hemorrhoidectomy is ordinarily indicated at a later date.

For those patients requiring some type of hemorrhoidectomy, arrange-

ments for operation may be made at a convenient time. They should be admitted to the hospital a day prior to operation. No attempts are made to empty or sterilize the bowel completely. A tap water or saline enema is given a few hours before operation but no cathartics are administered.

Anesthesia.—The ideal anesthesia for anorectal surgery must be safe, with a minimum of complications and no sequelae, and provide adequate relaxation. At the clinic, anorectal surgery is done whenever possible with the patient in the prone position because of the improved exposure and lessened vascularity of the parts involved. The inhalation types of anesthesia have in general not been entirely satisfactory with patients in this position because of the difficulty in breathing. Deep ether anesthesia, it is true, gives adequate relaxation but the technic of administering ether with the patient in the prone position is unsatisfactory and the postoperative discomforts are not desirable.

The intravenous use of the barbiturates has been advocated by many. The barbiturates are safe but except with very experienced anesthetists frequently do not provide adequate relaxation and, with patients in the prone position, are not highly desirable in many instances because of the difficulty in breathing and the frequent requirement of oxygen supplementary to the anesthesia.

Spinal anesthesia can be given rapidly, produces ideal relaxation and has been used for many years at the clinic for rectal surgery. Spinal anesthesia, however, produces an occasional very troublesome postoperative headache, and for this reason is being employed less and less for surgery of this type.

At the present time for most anorectal surgery, caudal anesthesia is being employed almost routinely. The technic of administering caudal anesthesia by inexperienced anesthetists is at times trying to the patient, but this can be minimized with experience. Relaxation is satisfactory, and postoperative complications are at a minimum. In our experience with large numbers of patients being given anesthesia of this type, the only complication that has been observed is an occasional complaint of soreness and tenderness in the region of the needle puncture, probably due to a periosteal reaction. This has never produced serious or permanent sequelae. The addition of transsacral anesthesia to the caudal block has been abandoned as unnecessary.

For caudal anesthesia, a single needle is introduced into the caudal canal; 25 to 30 cc. of 1.5 per cent metycaine or 2 per cent procaine, combined with 2 to 3 minims of 1 to 1000 epinephrine as a vasoconstrictor, is employed. Fifteen to twenty minutes should be allowed for the attainment of adequate relaxation. Nearly 100 per cent of the patients will have satisfactory anesthesia if this policy is followed.

Technic of Hemorrhoidectomy.—The type of hemorrhoidectomy which is utilized at the clinic at the present time does not differ materially from that previously described in 1939¹ and 1942.⁴ This technic is reviewed in the accompanying illustrations (Figs. 330 to 335).

The patient is placed in a prone position with the hips slightly elevated with a 4 to 6 inch blanket roll. This allows the pelvis to be tipped forward, the anal canal to be almost in an upright position, more satis-

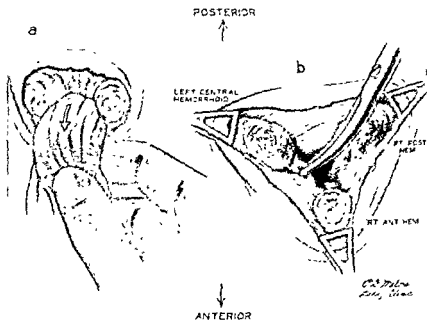


Fig. 330—*a*, Demonstration of internal hemorrhoids and prolapse of anal mucosa by withdrawing dry gauze from the rectum.

b, Following gentle digital stretching of the anal musculature, exposure of the anal canal and hemorrhoids is obtained by placing Pennington clamps on the margins of the anal canal. Emphasis is placed on excision of the primary "piles" usually found in the right anterior, right posterior and left central positions. Hemostasis is first obtained by placing a clamp on the superior hemorrhoidal vessels.

factory exposure of the parts than with the lithotomy position, and there is much less vascularity. At the present time other positions are not employed except for an occasional instance in which a hemorrhoidectomy is combined with a pelvic procedure, necessitating the lithotomy position for the major part of the operation. In general, however, multiple operations are not done, and frequently if a patient is to have a gallbladder procedure or some abdominal operation in addition to the hemorrhoidectomy, the latter procedure is deferred until a later date.

Occasionally patients come to the operating room for anorectal procedures who have not had a sigmoidoscopic examination. This is usually

because at the time of the original examination they were in so much distress or the examination was so painful that instrumental examination could not be done. We have adopted a policy which has been followed for many years of sigmoidoscopy any patient who comes to the operating table for an anorectal procedure who has not previously been sigmoidoscoped. This is done under anesthesia if necessary. If this could be adopted generally it would be impossible to perform a hemorrhoidectomy in the presence of a neoplasm of the terminal bowel.

When anesthesia is adequate and the operative field prepared for surgery, a gentle digital stretching of the anal canal is done. Strenuous

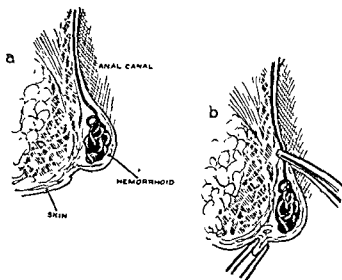


Fig. 331.—*a*, Diagrammatic cross section of the anal canal with a prolapsing hemorrhoid
b, A clamp has been applied to the superior hemorrhoidal vessels proximal to the hemorrhoidal mass

dilatations or divulsions of the anal canal are never performed. This in itself has been responsible for much of the bad name that has been given hemorrhoidectomy in the old clamp-and-cautery days. When scar tissue is encountered or there is actual fibrosis of the subcutaneous division of the external sphincter muscle, referred to by some as pectenosis, it is preferable to divide this scar tissue or fibrosis surgically. This is not done routinely, but we do not hesitate to perform this procedure when the anal canal is contracted.

An anoscope is then introduced into the anal canal, the obturator removed and the rectum filled with a dry gauze strip, the anoscope removed, and by gentle traction on the gauze strip, the size and extent of the hemorrhoid to be dealt with can be accurately determined.

The type of hemorrhoidectomy described is similar to that generally employed by the majority of proctologists at the present time. Many

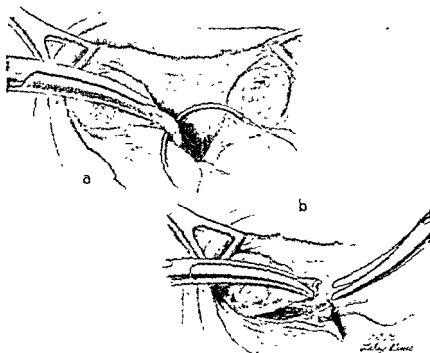


Fig 332 —a, A ligature is placed around the superior hemorrhoidal vessels of the pile pedicle b, The pile is excised distal to the ligature. This incision is carried down to the underlying musculature and removes all hemorrhoidal tissue.

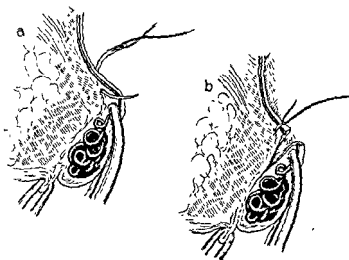


Fig 333 —Diagrammatic cross section of Figure 332, illustrating, a, ligation of the superior hemorrhoidal vessels and, b, the beginning of the excision of the hemorrhoidal mass

rectal surgeons reverse the procedure by beginning the excision of the hemorrhoidal mass from the outside and working in. We have never

fully appreciated the rationale of this method and have always placed a preliminary ligature around the pedicle of the "pile" before excising the hemorrhoidal mass. This ligature, if properly placed, controls much of the bleeding and allows an accurate surgical dissection of the lesion to be removed. Particular attention is given to the three primary "pile" pedicles in the right anterior, right posterior and left central positions.

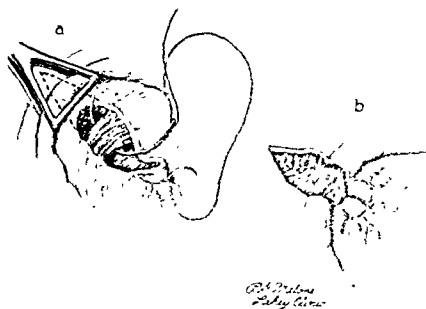


Fig 334.—*a*, Mucosa of the anal canal is completely restored by anchoring the pedicle to the subcutaneous division of the external sphincter muscle

b, External hemorrhoidal mass with overlying skin tab is then excised, leaving an open V-shaped wedge for drainage

In more extensive processes, hemorrhoidal tissue can be excised between areas by undercutting. The preservation of intact areas of skin and mucous membrane between these defects leaves a more desirable end result than that following the plastic amputative types of operation or any such modification of the Whitehead procedure.

When secondary radicals are present they can, many times, be excised in a similar fashion.

Ten years ago we performed quite a number of hemorrhoidectomies of the plastic amputative type, as advocated by Buie. This procedure was performed on those patients with extensive hemorrhoids, usually involving the entire anal ring and accompanied by varying degrees of prolapse of the anal mucosa. In general, this procedure gave excellent results although in many of these patients some narrowing and also some shortening of the anal canal was encountered postoperatively. The latter condition was particularly prone to occur in women who had

borne children and who had some relaxation of the perineum. At the present time we rarely employ the amputative type of hemorrhoidectomy except in those plastic procedures in which excision of excess anal mucosa is required

Bacon and others have described methods of undercutting the anal skin and mucosa between the segments occupied by the primary "pile" pedicles, excising the hemorrhoidal tissue in those areas and leaving an intact bridge of skin and mucosa at those points. This has seemed to us a desirable improvement in our technic and we have employed this principle more and more. It does increase the amount of bleeding at the time of operation and at times light packing for a few hours following operation is indicated

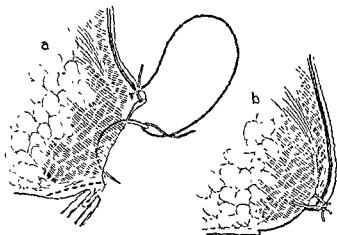


Fig 335 —Diagrammatic cross section of Figure 334, illustrating, a, anchoring of the pile pedicle to subcutaneous division of the external sphincter muscle and, b, restoration of the anal mucosa to its normal position at the mucocutaneous line

Hemorrhoidectomy may be said to have been satisfactory if the anatomical and functional results are good and the patient has not undergone an undue amount of discomfort following the operation. Many experienced rectal surgeons routinely employ one of the procaine-in-oil preparations injected into the sphincters for the control of post-operative pain. We have attempted this in a small series of cases twice in our experience. On both occasions after a number of procedures, complications have resulted and we have abandoned the practice.

It is our belief that with meticulous attention to certain details, post-operative pain following hemorrhoidectomy can be minimized and injections into the anal musculature at the time of operation are not necessary. There must be no undue trauma at the time of operation, a minimum of stretching of the muscles, clean surgical dissection of the lesion

to be removed, adequate hemostasis, and large packs or plugs should not be placed in the anal canal postoperatively. Following hemorrhoidectomy it is our practice to cover the operative defects lightly with a small petrolatum strip covered with dry gauze, and the buttocks are strapped tightly with adhesive.

After-care.—Our nurses in charge of these patients are carefully instructed that massive, hot wet dressings are to be applied to the anal area as soon as anesthesia has worn off and before muscular spasm begins. Postoperative pain following hemorrhoidectomy is due to muscle spasm. If massive, hot wet packs can be utilized before this spasm occurs, these patients will have a minimum of postoperative discomfort. Our practice in this regard has followed that of Buie. The patients are turned from side to side every hour and the massive hot saline dressings are changed at those times. These dressings are made up of a mass of wet saline gauze, a large towel, a hot water bottle or two and one or two pillows to keep the dressing in place.

Since we have faithfully followed these principles we have not found it necessary to inject anesthetic-in-oil preparations in the perianal muscles at the time of operation for the control of postoperative pain. The majority of our patients require an average of one hypodermic injection after operation.

Difficulty in voiding following rectal procedures is not uncommon, particularly in older male patients. Such patients are allowed out of bed at any time and given the usual encouragements. Postoperative urinary complications are not a serious problem.

On the second or third postoperative day if the patient so desires, the hot packs are discontinued and the patient is allowed to have one, two or more hot sitz baths daily. On the morning of the third postoperative day a small oil retention enema is given. On the morning of the fourth day, if required, a 3 pint saline enema is given. On either the third or the fourth postoperative day gentle digital stretching of the anal canal is carried out by a physician with a well-lubricated gloved finger. The object of this procedure is not to dilate the anal musculature but to separate the edges of the operative wound so that bridging and excessive scar formation will not occur. This procedure is performed either by us or by the home physician every three or four days until the operative defect has healed, which averages between three and four weeks. Patients are usually discharged from the hospital on the fourth or fifth postoperative day with instructions to continue their sitz baths as they are required for comfort and for local cleanliness and to be examined by a doctor at least every third or fourth day.

During this postoperative period considerable attention is also given to the correction of bowel habits. A high percentage of patients with

ions as follows: (1) faulty coalescence of the lateral halves of the body; (2) sequestration owing to inclusion of epithelium (Bland-Sutton); (3) ectodermal invagination (Llanellongue); (4) persistence of a coccygeal vestige of the neural canal (Lourneau and Herrman), (5) pituitary dysfunction (Rosser), and (6) vestigial remains of the preen glands (similar to the organ found in birds which exudes an oily substance used in preening their feathers and possibly for sexual attraction).

The pathologic findings of pilonidal sinus disease are variable. A sinus tract is present, usually lined by stratified squamous epithelium with some cornification. Hair follicles and coil gland formation are frequently apparent. The term pilonidal cyst derives from the fact that commonly the sinus tract ends in a cystic dilatation occupied by the products of skin secretion and forming a palpable tumor mass. Following the introduction of an inflammatory process all stages from an acute abscess to chronically infected sinus tracts with multiple draining sinuses may be present. The usual report received from the pathologist of tissue removed at operation is "chronic inflammation, compatible with pilonidal sinus."

TREATMENT

The treatment of pilonidal sinus disease is surgical and depends on the degree of inflammation present. In the presence of an acute abscess or in the chronically infected sinus tract with inadequate drainage, preliminary treatment consists of adequate surgical drainage.

Treatment of the chronically infected, adequately drained pilonidal sinus consists in the surgical removal or destruction of all involved tissue, with subsequent complete healing of the defect.

Attempts have been made in the past at various chemosurgical methods,³ such as repeated injections of a modified Carnoy's solution into the sinus tracts. These methods have not been universally accepted. In general, there have been only two accepted methods of surgical treatment. (1) the open method of treatment which has consisted of a radical excision of the disease-bearing tissue, allowing the wound to heal by granulation, and (2) excision of the disease-bearing tissue, with primary closure of the wound.

As an example of the change in attitude of the members of the American Proctological Society the following studies have been reported:

Kleckner, in a pre-war review of the opinions of this group found that 87 per cent preferred the open method of surgical treatment. Rosser and Kerr conducted a post-war survey of 27 proctologists who had been in military service and found that 77 per cent still favored the open operation for civilian practice. However, 18 per cent preferred primary closure with certain stipulations. It was Rosser and Kerr's opinion, in spite of

this predominance of favor for the open operation, that there were many strong arguments for the primary closure of these wounds.

Open Operation.—In considering the group of patients treated in the past by the open method of operation, it must be appreciated that continued improvement with the open type of operation was made during this period. The earliest patients in our series were treated by a radical block excision, removing large segments of the skin and all underlying tissue down to the presacral fascia. Many of these patients presented operative defects which were not completely healed for many months and large, painful scars persisted, sometimes permanently.

In 1932, Lahey reported a flap operation. This consisted of a radical block excision of all diseased tissue, but rather than allow this operative wound directly over the lower sacrum and coccyx to heal secondarily, a flap formed by means of an elliptical incision made parallel to the original defect was swung into the defect. The blood supply of this flap was maintained at either end. This procedure had a limited usefulness in a small number of patients and at the present time has not been employed for several years. Many of these operative wounds became secondarily infected, broke down and healed by secondary intention, defeating the purpose of the flap. Rogers later reported an open type of operation which seemed to us a decided improvement on previous technics and, with slight modifications, is still employed at the clinic. This consisted of an incision of the sinus tracts with little or no skin being removed. Accurate dissections of the underlying process were then made, with the removal of a minimum of subcutaneous tissue. We have usually performed this procedure with an electrosurgical unit, cauterizing the incised sinus tracts and not attempting to excise all scar tissue. No attempts are made to continue the dissection down to the presacral fascia unless actual pathologic change is found at this level.

The wounds are lightly packed with petrolatum gauze and the patients either sent directly home from the clinic or, if hospitalized, discharged within one to three days. Dressings are changed as an out-patient procedure on the third or fourth day and the wound gently swabbed with Carnoy's solution, a cauterizing agent, and the wound gently curetted with a small bone curet. This procedure is repeated two or three times at three to four day intervals. At the end of ten to twelve days the wounds are clean, all diseased tissue has been removed, they are granulating satisfactorily, and the patients have returned to their occupations. The average healing time for wounds treated in this manner is approximately six weeks.

In considering the group who have been treated by some type of open operation, the following conclusions may be drawn: (1) the period of hospitalization is minimal. Many of these patients can be treated as out-

patients or office patients. In our series, 54 patients treated by this method averaged 58 days in the hospital. As previously stated, with the more recent types of incisions and emphasis on the removal of a minimum amount of tissue this time can be materially reduced further. (2) The time lost from work for these patients was brief. The majority have been able to return to their usual occupations in a few days to two weeks. (3) The period of time for the wound to heal completely, however, was prolonged. The average healing time of the 35 patients followed in this group was 103 days or 3.4 months. In the more recent cases in this series the wounds were healed in approximately six weeks. (4) The end results from the standpoint of recurrence have been excellent. Only 1 of the 30 patients who have been followed at the present time required further surgery. (5) Many of these patients have had resultant painful scars. In reviewing these cases the majority of patients have complained, and some quite bitterly, of persistent pain and tenderness in the region of the scar, over the coccyx and lower sacrum, even after many years. Rogers has reported a similar experience. (6) The open method of treatment can frequently be used in the presence of extensive infection.

In summary, then, it is our belief that the open method of treatment as has been performed more recently at the clinic has been satisfactory from the standpoint of recurrence, with a minimum of expense to the patient as regards hospitalization and time lost from work, but the prolonged healing period and resultant painful scars have been objectionable features.

Closed Method of Treatment.—A variety of technics has been described for the excision of pilonidal cysts and sinuses followed by primary closure and healing of the wounds. For the small, simple, uncomplicated pilonidal sinus lying in the midline over the coccyx, simple excision and closure of the wound is probably the treatment of choice. However, in the more extensive processes following the development of multiple sinus tracts, extensive abscess formation and previous surgery, excision and primary closure may be a complicated technical procedure.

Most observers^{2,6} have pointed out that it is desirable to remove a minimum of skin and underlying tissue and yet completely remove all pathologic tissue. It is probably desirable to have a minimum of the resultant scar in the midline where it is subjected to the trauma of sitting and also to the lateral pull of the buttocks. It probably also is desirable to restore the normal fat pad over the coccyx and lower sacrum.

The technic of the operative procedure which has been followed at the clinic for the majority of the patients who have had excision and primary closure is described in the accompanying illustrations. A minimum of skin is removed. The initial incision is long and narrow (Fig. 336, a). The defect, however, is carried down to the presacral fascia. Lateral

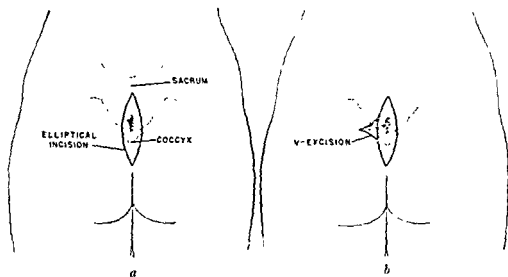


Fig 336—*a*, Narrow elliptical incision centered on midline over coccyx, carried down to presacral fascia.

b, For excision of sinus openings and tracts not included in the initial elliptical incision, V-shaped wedges may be made, excising such sinus tracts, followed by immediate primary closure of the defect.

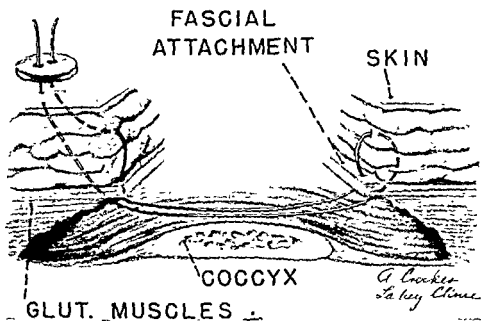


Fig 337.—Incision of fascial attachments of glutei to the lateral borders of the coccyx and lower sacrum. These incisions may be extended laterally into the muscle of the glutei so that the fascial attachments may be approximated in the midline anterior to the coccyx without tension. Placement of wire retention sutures illustrated.

sinuses are excised by V-shaped incisions (Fig. 336, *b*) extending outward from the primary approach, diseased tissue removed, and the sinus tracts closed. The fascial attachments of the glutei to the coccyx and

lower sacrum are then incised (Fig. 337), and approximated in the midline over the coccyx and lower sacrum with a layer of interrupted chromic sutures (Fig. 339). This is the only catgut or suture material of any type in these wounds. All dead spaces are completely obliterated with wire retention sutures (Fig. 338). The remaining wound consists of a freely movable block of tissue over the coccyx forming an adequate replacement of removed tissue.

It is true that the remaining scar is in the midline. It is small, however, and to date we have not had any difficulty with the breaking down of these wounds from the lateral pull of the buttocks. The remaining fat

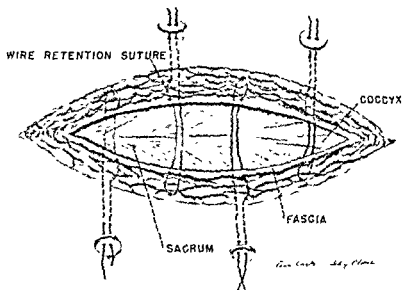


Fig 338 —Anteroposterior view of wire retention sutures in place.

pad has eliminated the complaint of painful scars, mentioned by so many of our patients treated with the open method.

It has seemed to us that the treatment of choice for pilonidal cysts and sinuses should not differ from the accepted treatment of other processes of this nature, such as thyroglossal cysts and sinuses, except for the fact that a scar overlying the coccyx is subjected to much more stress and strain than one in the neck. The type of excision and primary closure for pilonidal sinus disease performed by us has so far been able to withstand the unusual demands made on the tissues overlying the coccyx and lower sacrum.

In reviewing our series of cases treated in this manner, the following conclusions may be mentioned: (1) an appreciable period of hospitalization is required. In our series, the average of 46 patients was 10.5 days. (2) The amount of time lost from work averaged slightly longer than

when the open method was employed. (3) The wounds were uniformly healed at the time of discharge from the hospital. The long morbidity with frequent visits to the physician, and stained dressings were avoided. (4) The incidence of recurrence has been minimal. At the present time 21 patients treated in this manner have been examined. Two have required further surgical intervention but, following this secondary procedure, they are completely healed. (5) Painful scars have been avoided. Examination of these patients following complete healing reveals an appreciable pad of fat, connective tissue and skin overlying the

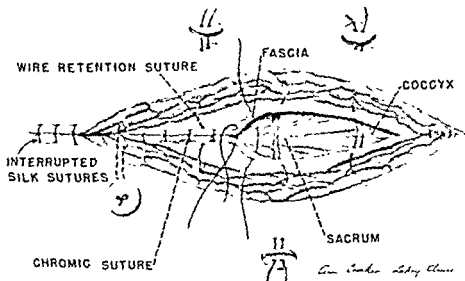


Fig. 339.—Closure of wound performed by a layer of fine interrupted chromic sutures approximating the fascial borders of the glutei anterior to the coccyx and lower sacrum with interrupted silk or fine wire sutures in the skin. The remaining wound is a freely movable block of tissue with all dead space eliminated. No attempt is made to anchor tissue to presacral fascia. Careful hemostasis is required. A minimum of catgut or other suture material is placed in the wound. The wound may be lightly dusted with sulfanilamide powder before closure.

Postoperatively, penicillin is given for five days, and bowel movements are prevented for seven to ten days by the use of a nonresidue diet and small amounts of tincture of odorized opium by mouth.

coccyx, which is comfortable and has eliminated the late complaints of pain and discomfort which followed the open method of treatment. (6) The closed method of treatment cannot be employed in the presence of an acute or extensive inflammatory process.

Conclusions.—At the present time, therefore, as a result of our experience with both types of treatment for pilonidal cysts and sinuses, we have adopted the following policies: (1) In the presence of acute or extensive infection, incision and drainage only should be performed. (2) For the small, uncomplicated, asymptomatic pilonidal cyst, simple

excision and primary closure is the method of choice. (3) For extensive pilonidal cysts and sinuses, where previous drainage has been required or when a minimum of secondary infection is present, the majority can be satisfactorily treated with excision and primary closure of the wound. This technic requires meticulous attention to certain technical details and ten to fourteen days of hospitalization. (4) Excision of diseased tissue followed by secondary granulation of the wound, after the method previously described in this article, may be necessary for those patients with inadequately drained sinuses who cannot be hospitalized for more than a minimum period of time and whose occupation is such that the resultant midline scar will not be a handicap to them.

It is our belief that, with further experience, by far the majority of pilonidal cysts and sinuses can be satisfactorily managed with the best possible end results by some type of excision and primary closure of the wound.

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MANAGEMENT OF VARICOSE VEINS OF THE LOWER EXTREMITY

CORNELIUS E. SEDGWICK

Varicosities of the greater and lesser saphenous systems are treated according to the severity and extent of involvement by a combination of ligations and injections. If the involved veins are minimal and limited to the lower leg, injections may suffice. If the varicosities are marked and extend above the knee, high ligation, retrograde injection and multiple low ligations at the sites of the incompetent perforating communicating branches are indicated.

High ligation means excision of a segment and ligation of the greater saphenous vein at its junction with the femoral vein and all tributaries of the saphenous vein at this site. There are usually four tributaries: the superficial circumflex iliac, the superficial epigastric, the superficial external pudendal and the lateral femoral cutaneous. However, there may be many variations and anomalies. There may be one to six tributaries. Occasionally, the tributaries of the saphenous vein empty directly into the femoral vein. It is important to ligate all of the tributaries in this region to insure a good result.

At this clinic, high ligation is performed most often under spinal anesthesia or local regional infiltration with 1 per cent procaine. A board is placed across the lower end of the operating table so that the leg and thigh can be abducted and externally rotated. This allows better exposure of the operative area. The saphenofemoral junction is the landmark for making the incision. This site is determined by two means and one is checked against the other. The saphenofemoral junction is two fingerbreadths below and lateral to the pubic spine, or two fingerbreadths below the inguinal ligament medial to the palpable femoral artery. The femoral artery is a constant landmark throughout the procedure.

An incision is made over the elected site below and parallel to the inguinal ligament for a distance of 6 cm. (Fig. 340). The superficial fascia is frequently seen as a distinct structure. It is divided and if the incision has been well chosen, the greater saphenous vein is found in the fatty tissue without difficulty. In searching for the saphenous vein care should be taken that the dissection does not go too deep, thus exposing the femoral vein rather than the saphenous vein. The saphenous vein is always superficial to the deep fascia and the femoral is deep to the deep fascia. The deep fascia is easily recognized by the lack of fat posterior to it. Frequently in exposing the saphenous vein lymph nodes are en-

countered. Care should be taken not to traumatize or incise these nodes. Occasionally, a wound will drain lymph for several weeks because the lymphatics have been disturbed.

The saphenous vein is completely separated from the surrounding fatty tissue for a distance of 1 to 2 cm. and then divided between clamps (Fig. 341, a). Division at this stage makes the exposure of the posterior tributaries easier. By using the clamp on the proximal stump as a trac-

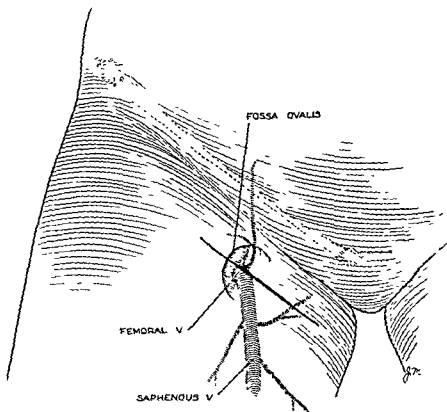


Fig 340—Incision

tor, the vein is lifted from its bed and the posterior vessels can be clamped and divided (Fig. 341, b). If the dissection is kept close to the adventitia of the vein, a plane is encountered and the fatty tissue can be swept away by a combination of blunt and sharp dissection. The tributaries are carefully clamped, divided and ligated. As the fossa ovalis is approached, a small artery is encountered running along the lower border of the superficial edge of the fossa ovalis posterior to the saphenous vein. This is the superficial external pudendal artery and it is a good landmark, indicating the fossa ovalis and the proximity of the sapheno-femoral junction. After all the tributaries have been divided the main

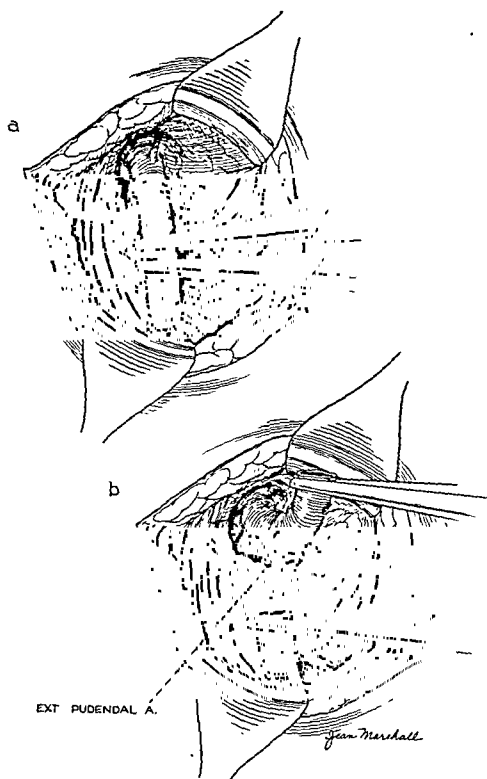


Fig 341.—*a*, Isolation and division of vein. *b*, Exposure of posterior tributaries (The label above should read, *Sup Ext Pudendal A*)

saphenous vein is doubly ligated close to the femoral vein and the excess vein excised.

Attention is then turned to the distal segment of the vein which is isolated from the surrounding fatty tissue and made ready for the retrograde injection (Fig. 342). It is easier to cannulate the vein with a cannula or blunt needle than to inject directly into the vein with a sharp needle. Also, with this method there is no chance of injecting into the wall of the vein rather than into the lumen. A moist sponge is placed in the wound in case there is any spillage of sclerosing solution into the tissues. If resistance is met when injecting the sclerosing solution, force should not be used. Resistance means the existence of competent veins and injection is unnecessary and should be abandoned. If there is no

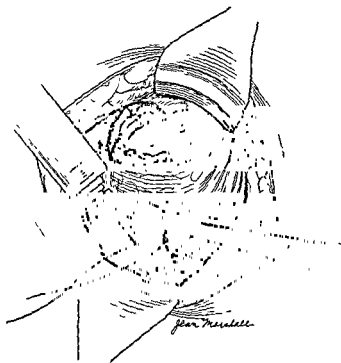


Fig. 342 —Injection of distal segment of vein

resistance, the fluid should be injected slowly and immediately be massaged down the thigh and leg. We have not found it necessary to instill the sclerosing solution with a ureteral catheter to the distal segments of the vein. The vein is tied distal to the cannula and the excess vein excised. The subcutaneous fascia and skin are closed.

Following high ligation and retrograde injection, multiple low ligations are performed at the sites of any incompetent perforating tributaries. These sites are determined and marked preoperatively. The low ligations are simple divisions and ligations of the greater or lesser saphenous

veins through short transverse incisions. The perforators may or may not be found and ligated. Occasionally, there may be several perforators close together. In such cases a transverse or oblique incision is made and a segment of vein is excised. The several perforators are then tied as they are found entering the segment.

A small gauze dressing covered with elastoplast is placed over the wound. This allows the patient to be up and around with a comfortable dressing that remains in place. Large bulgy dressings are uncomfortable, rub off, and frequently when the patient returns to the office for removal of the sutures there are stitch abscesses and low grade wound infections. The lower leg up to the knee is wrapped in ace bandages which remain on until the time of the first dressing. The patient is encouraged to be up and walk about on the day of operation.

The patient is discharged the day after the operation and is seen in the office about the fifth postoperative day. The sutures are removed and any residual varicosities are injected. Additional visits may be necessary to obliterate completely all superficial varicosities. At the conclusion of the treatments the patient is instructed regarding after-care. Constricting garters are to be avoided. He is encouraged to avoid long periods of standing and to elevate his legs whenever possible. If the varicosities were complicated with stasis ulcers and skin grafting, he is urged to wear fitted elastic stockings permanently. The patient's course is followed at six-month intervals for possible additional injections.

HAZARDS AND COMPLICATIONS

Although relatively minor operative procedures, saphenous vein ligation and retrograde injection are associated with certain hazards and complications which should be brought to the attention of all doing this procedure. Recently, Luke and Miller* reported a series of 21 disasters following the operation of ligation and retrograde injection of varicose veins. The disasters included: tear and subsequent ligation of the femoral vein, fatal hemorrhage in a patient with a damaged cardiovascular system from a torn femoral vein, division and injection of the femoral artery with subsequent mid thigh amputation, and thrombosis of the deep veins with pulmonary embolization. These disasters occurred with experienced as well as inexperienced surgeons. All too often, however, this procedure is left to the most inexperienced intern or member of the surgical house staff to be done in an out-patient department without proper operating room facilities and without assistants. Usually, because of poor exposure and rough handling of fragile veins, serious venous

* Luke, J. C. and Miller, G. G. Disasters following the operation of ligation and retrograde injection of varicose veins. *Ann. Surg.* 127: 426-431 (March) 1948.

bleeding results. This may lead to blind clamping and damage of important neighboring structures.

If these disasters are to be prevented, the surgeon performing this procedure should have all the advantages and facilities of a well-run operating room, with good light and proper assistants. It is imperative to know the regional anatomy: the saphenous vein and its tributaries, the relationship of the saphenous vein and the femoral vein and artery and the relationship of the fossa ovalis to the deep fascia. A meticulous dissection must be carried out.

If severe hemorrhage is encountered it should be controlled with pressure. The patient should be checked for proper anesthesia and blood for transfusion should be obtained. If local anesthesia is being used general anesthesia should be instituted. If the patient's condition is satisfactory, the wound can be carefully explored through an enlarged incision with adequate exposure. A bleeding tributary can be isolated, clamped and ligated. A tear in a femoral vessel should be repaired rather than ligated, followed by anticoagulant therapy.

Deep venous thrombosis and pulmonary embolus are constant threats. There is no doubt that some of the retrograde injected sclerosing solution occasionally finds its way into the deep veins and is responsible for some cases of postoperative deep thrombophlebitis and pulmonary embolus. To prevent this complication we use a limited amount of a weaker sclerosing agent (5 to 10 cc of varisol*) and have the patient ambulatory as soon as possible following the operation.

With this plan of management and with these precautions we have obtained extremely good results in the treatment of varicose veins of the lower extremity.

* Varisol (inert sugar, sodium chloride benzyl carbinol), Abbott Laboratories.

THE SURGICAL TREATMENT OF FRACTURES OF THE LATERAL TIBIAL CONDYLE

G. E. HAGGART AND HOWARD M. CLEMMONS

Fracture of the lateral condyle of the tibia can be and often is a cause of marked permanent disability, because in the more severe injuries, which so frequently occur, there is comminution of the articular cartilage with dissolution of the spongy bone below, together with tearing, crushing or displacement of the lateral meniscus. The failure to remove the damaged meniscus and then accurately reduce the fracture results in knock-knee deformity, lateral instability, and a persistent chronic synovitis.

Fractures of the lateral tibial condyle are the result of sudden abduction of the tibia on the femur and are caused by: falls from a height; a twisting injury, or the most common agent—a blow on the lateral side of the knee, from the bumper or fender of an automobile as reported by Cotton and Berg and by Cubbins, Conley and Seiffert in 1929. These authors also emphasize the frequency with which the lateral meniscus is injured, pointing out that it might be jammed down in between the fragments of the tibia, thus preventing any possibility of accurate, closed reduction.

An additional reason for operative exposure of all severe fractures of this type and many of the ones of questionable severity is that the roentgenograms do not accurately reveal the extent of the injury because of the overlying bone shadows. For example, in an anteroposterior view, the posterior rim of the lateral condyle casts a shadow which may obscure the degree of the depression of the central and anterior aspects of the lateral plateau, while the lateral roentgenogram as such is usually of little value because of the overlapping shadows from the medial condyle. Anteroposterior stereoscopic and right and left oblique roentgenographic projections have been found most helpful.

With a normal level of the condylar plateau of the tibia, the stability of the knee joint depends upon the integrity of the strong supporting ligaments, particularly the lateral and medial collateral ligaments together with the surrounding muscles, whereas in the presence of a depressed surface of this condyle these ligaments and the muscles as well are at a marked disadvantage. Disability from this fracture is accentuated by the fact that the normal medial inclination of the femur causes more stress on the outer than on the inner femoral and tibial condyles.

TREATMENT

The management of fractures of the lateral tibial condyle can well be considered under the classification reported by Barr, together with one additional group, later emphasized by Cave.

Type A, in which careful roentgenograms reveal less than $\frac{1}{4}$ inch displacement, is best treated by suspension, together with aspiration of the joint as seems indicated. Close-fitting plaster casts may be used. It is important to institute early active exercises of the quadriceps muscle groups and in two weeks begin active motion of the joint. An intelligent, cooperative patient may be allowed up with crutches in six to eight weeks but no real degree of weight bearing is permitted for ten to twelve weeks.

Type B, wherein the roentgenograms exhibit slight to moderate displacement of $\frac{1}{4}$ to $\frac{1}{2}$ inch, is the group in which there is a question as to whether the fracture site should be explored or handled on a conservative basis. In most instances we have favored open exploration because, as noted above, the roentgenograms so consistently failed to reveal the actual extent of the pathologic process. On the other hand, it is fair to point out that some patients who exhibited a fracture approaching a $\frac{1}{2}$ inch displacement and for whom we believed surgery advisable have achieved an excellent clinical result although the roentgenograms show far from an anatomical reposition of fragments.

Type C, moderate to marked displacement, in other words, $\frac{1}{2}$ inch or more, is the group in which open operation is always indicated, because closed reduction and manipulation simply result in impaction of the central fragments in a displaced position.

Type D is the group in which there is extensive comminution of the entire upper end of the tibia or what has been termed a bursting fracture. In these patients the tibia is so shattered that an open procedure is ill-advised. They are primarily treated by skeletal traction through the lower end of the tibia, together with gentle manipulation under anesthesia at the time of the application of the traction. This program also offers the possibility, once healing has occurred and if the plateau level is not restored, of later operating to replace the condylar surface.

TECHNIC OF OPERATION

The fracture site is exposed (Fig. 343) by a lateral incision running in front of the fibula and lateral to the patella as described by Leadbetter and Hand, extending sufficiently above and below the joint line to permit good visualization of the fragments as well as to allow access to the proximal aspect of the tibia so that a bone graft may be obtained. A tourniquet is employed.

The joint is thoroughly washed out with saline solution to remove blood clots and then the fracture site is inspected after subperiosteal dissection of the exposed portion of the tibial condyle, leaving the soft

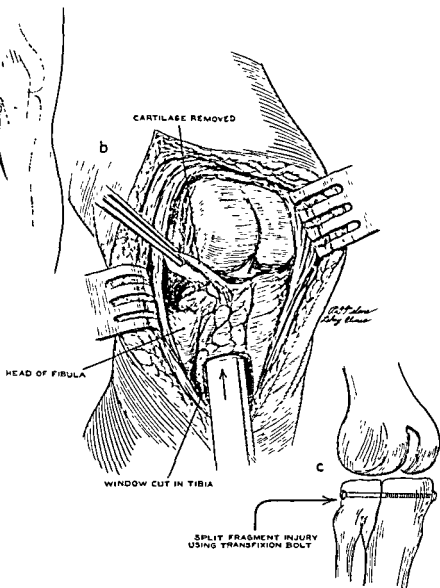


Fig 343 —The operative procedure. Note window cut in tibia that permits the insertion of a blunt instrument to aid in restoring the level of the cartilaginous surface as well as to pack bone fragments against the cartilage supporting the plateau, in each instance utilizing the condyle of the femur as the opposing surface. The meniscus has been lifted up out of the depressed fracture area and, as here illustrated, has been freed from its lateral attachments for removal *in toto*

parts attached to the lateral fragments of the tibia. The injured lateral meniscus is first removed *in toto*, thus allowing a still better view of the fractured articular surface of the tibia; it is then possible, with the use of elevators, to reposition the depressed plateau and this is further ex-

pedited by cutting a small window in the proximal anterolateral aspect of the tibia which will permit a blunt instrument to press against the inferior surface of the condyle. In addition, once the fragments are repositioned, cancellous bone removed from the upper end of the tibia is packed into this space, utilizing the opposing lateral condyle of the femur as a surface against which to press.

When a fragment is split off, either the entire condyle or a considerable portion thereof, fixation is maintained by a transfixion bolt passed across the upper end of the bone (see Fig. 345).

When the entire tibial condyle is crushed down (see Fig. 348, *a*) or in the cases of old fracture with marked depression and instability of the knee (see Fig. 346), cortical bone grafts removed from the upper end of the tibia are employed as supporting struts after osteotomizing the condyle, lifting it up and, with the aid of the strut, restoring a normal level of the tibial plateau.

POSTOPERATIVE CARE

In these severe fractures the patient is first placed in a plaster cast unless it is thought that there is extremely firm fixation of the fragments as, for example, when bolts are employed, in which event the extremity is placed in suspension with light traction to the lower extremity. Plaster fixation is maintained for a minimum of six weeks but those individuals in suspension are started on motion in seventy-two hours. All patients are instructed in muscle setting exercises.

None of these patients are allowed any weight bearing for ten weeks and then only with two crutches and wearing a caliper brace. The patient is instructed simply to place the foot on the floor for balance. It is most important that none of these patients with severe fractures be permitted to bear full weight until six months' time has elapsed. In those patients with minimal displacement of fragments and on whom operation was not performed, full weight bearing is started in progressive stages after three months have elapsed.

In all patients with severe fractures originally immobilized in plaster, and in occasional cases treated by suspension and traction, we have found that eight to ten weeks following reduction, gentle manipulation of the joint under intravenous pentothal anesthesia, with the patient prone, has materially hastened the return of normal knee flexion.

ILLUSTRATIVE CASE REPORTS

CASE 1.—A 37 year old garage proprietor was admitted to the hospital on October 9, 1945. He stated that twenty-four hours previously he had fallen from a height of about 5 feet, followed by immediate complete disability because of the left knee.



Fig. 844 (Case 1).—Admission roentgenogram. Note the marked depression of the plateau of the lateral tibial condyle, the fracture line extending down into the proximal tibial shaft. At operation this fragment was completely separated from the shaft of the tibia.



Fig. 845 (Case 1).—a and b, Three years and nine weeks after open reduction. Knee joint motion is normal and the patient is asymptomatic. Note absence of any reaction about the bolt.

On examination, the knee was markedly swollen, there was pronounced tenderness along the joint line and roentgenograms (Fig. 344) revealed a depressed fracture of the lateral condyle of the tibia which had been displaced downward and outward.

At operation on October 15, 1945, there was extensive comminution and crushing down of the entire articular surface of the lateral tibial condyle. The posterior rim of the plateau had been broken up into multiple fragments. Anteriorly the rim was part of a large triangular fragment which had been displaced outward and downward. The central portion of the plateau immediately adjacent to the tibial spine had been impacted distally. The lateral semilunar cartilage (and this is important) was imbedded in several places in the fissures and fractures of the tibial plateau.

Following removal of the external meniscus the fragments of the articular surface of the tibial condyle were replaced in position, then the large lateral fragment was aligned and held by a transverse bolt.

The operative wound healed by first intention and when last seen on December 17, 1948, the patient was completely asymptomatic in regard to the knee, and had a normal range of motion. The roentgenograms (Fig. 345, a and b) revealed a normal articular surface and contour of the lateral tibial condyle.

CASE 2—This 34 year old housewife was admitted to the clinic on April 3, 1945, with a variety of symptoms and, in relation to the left knee, a sense of weakness and instability of some seven months' duration. She had been thrown from a truck, and thereafter one of the wheels of the truck passed over her leg (August 26, 1944). On clinical examination she exhibited a very unstable joint with marked weakness of the quadriceps musculature. Roentgenograms (Fig. 346) revealed a downward displacement of the external condyle of the left tibia. The patient also was found to have essential hypertension as well as chronic cystic mastitis. She was, therefore, originally admitted to the hospital for a right and then a left splanchnicectomy, followed by excision of the mastitis. During this period she was given intensive muscle exercises and instructed to lose weight, as she was definitely obese.

With return of the blood pressure to a normal level, the patient was readmitted to the hospital. On January 6, 1947, the knee was operated on and a heavy cortical graft of tibial bone was placed underneath the osteotomized lateral condyle which had been lifted into position. Eight weeks later, manipulation of the knee was carried out to expedite obtaining increased range of motion.

When the patient was last seen January 27, 1948, the roentgenograms (Fig. 347) anterior, posterior oblique and lateral views, revealed maintenance of the plateau level. The joint was absolutely stable, and examination of the knee was negative and the range of motion normal. The patient's only complaint was of fatigue of the extremity when she was tired, but it was our belief that this was because she had not properly carried out her muscle training, and she was therefore instructed to resume it more vigorously.



Fig 346 (Case 2).—*a*, Old, markedly displaced fracture of the lateral tibial condyle. Original injury, August 26, 1944, operation January 6, 1947. The opposite knee is shown for comparison (*b*).

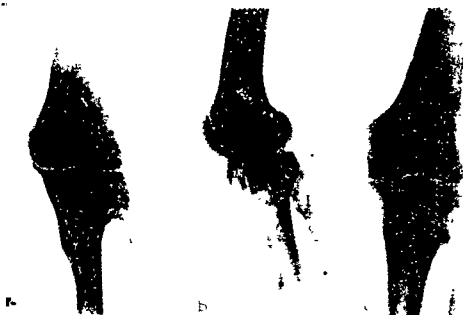


Fig 347 (Case 2).—*a*, *b*, and *c*, One year and three weeks after open reduction. Plateau level has been maintained, and bone grafts (see text) are almost indistinguishable. Note site of removal of bone grafts from the tibial shaft. Patient had normal range of motion and a stable joint.

CASE 3—A 20 year old secretary was admitted to the orthopedic service on April 10, 1946, following an injury sustained when struck by a motor car thirty-six hours previously. She arrived at the hospital in a long-leg plaster cast.

Clinical examination revealed marked abnormal mobility in the knee joint and the roentgenograms (Fig. 348, *a* and *b*) exhibited, in comparison with the opposite or uninjured knee, pronounced compression fracture of the entire lateral condyle of the left tibia.

At operation, on April 22 of the same year, numerous fissure fractures were seen running throughout the cartilaginous surface of the lateral tibial condyle, in one of which the semilunar cartilage was partly buried. In addition, this cartilage revealed a longitudinal split throughout its posterior two-thirds.

Following removal of the external meniscus, the cartilaginous surface of the lateral tibial condyle was lifted up by an osteotomy of this part of the bone carried out parallel to the articular surface, employing the central portion of the condyle as a hinge. A triangular piece of bone cut from the tibia was inserted into this defect and trimmed to fit.

The patient convalesced uneventfully following this procedure and when last seen January 8, 1949, the roentgenograms (Fig. 349, *a* and *b*) showed the graft incorporated within the tibia and the general level of the plateau was maintained. The knee joint was stable and painless. The patient's range of motion was from normal active extension to a flexion of 20 degrees beyond a right angle. She lacked at least 20 degrees of complete flexion as compared with the opposite side, which in our opinion was attributable to the difficulty that was encountered throughout our experience with the patient in having her carry out her exercise program.

CASE 4—A 31 year old housewife with a known history of diabetes mellitus was admitted to the orthopedic service on July 23, 1948, with a history of a twisting injury of the knee that occurred three weeks before admission and from which she was completely disabled.

Physical examination showed marked swelling of the joint and the roentgenograms (Fig. 350, *a* and *b*) revealed a depressed comminuted fracture of the external condyle of the tibia together with displacement of the lateral fragments of the condyle.

On July 27, 1948, open reduction of the fracture was performed, with removal of the obviously damaged lateral meniscus and elevation of the markedly comminuted fragments of the tibial condyle. Postoperative convalescence was uneventful. Originally placed in a long-leg plaster cast because of the extensive comminution of the fragments that was so pronounced it was not possible to utilize bolt fixation, and in which apparatus it was necessary to maintain the extremity until there was beginning evidence of healing, the joint was then progressively mobilized. When the patient was last seen February 4, 1949, the roentgenograms (Fig. 351, *a* and *b*) showed healing of the fracture, now over six months since operation, with maintenance of the tibial plateau. There was no evidence of swelling on examination and the patient was free of any pain or

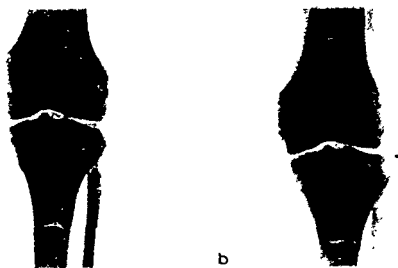


Fig. 348 (Case 8).—*a* and *b*, Comparative roentgenograms of the injured (*a*) and non-injured lateral tibial condyle. Note the marked depression of the entire lateral tibial condyle (*a*) without any clear-cut evidence of a fracture line. The joint was extremely unstable.

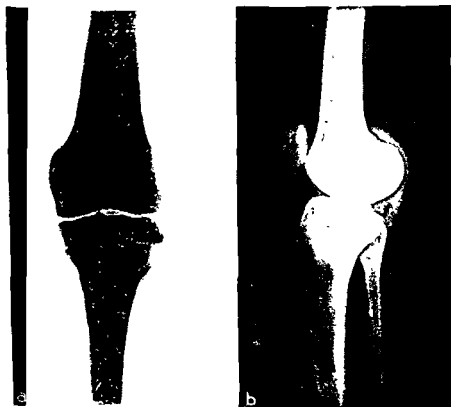


Fig. 349 (Case 9).—*a* and *b*, Two years and eight months following open reduction. Bone grafts are still evident. The knee joint is stable and painless.



Fig. 350 (Case 4) —*a* and *b*, Oblique and anteroposterior roentgenograms of a three-week old, extensively comminuted, depressed fracture of the lateral tibial condyle

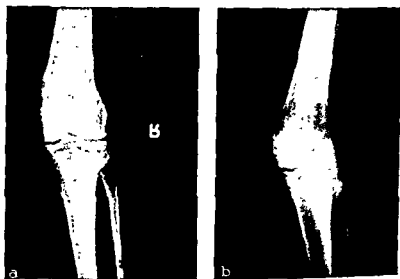


Fig. 351 (Case 4) —*a* and *b*, Comparable roentgenograms six months after open reduction. The normal level of the plateau has been maintained. There is no pain or swelling on motion. When last examined six months postoperatively the patient exhibited normal extension and lacked 10 degrees of flexion as compared with the opposite knee, but it is believed that in the very near future she will establish normal range of flexion.

discomfort. She exhibited normal extension and flexion within 10 degrees of the range present in the opposite or uninjured leg. The quadriceps musculature was still weak but was rapidly regaining tone and strength. The prognosis appeared favorable.

SUMMARY

Fractures involving weight-bearing joints should be restored to normal anatomical relationship as accurately as possible. To meet this criterion in fractures of the lateral tibial condyle with moderate or marked displacement of fragments, it is necessary to expose the fracture site, with the single exception of the so-called bursting type of fracture, which is treated by skeletal traction.

The operative approach is additionally indicated because the roentgenograms do not accurately reveal the extent of the injury owing to overlapping of the bone shadows.

It is admitted that some patients with moderate displacement of fragments who refused surgery have obtained a satisfactory functional result, although the roentgenograms continue to show an appreciable depression of the tibial plateau. Nevertheless, presented with a fresh fracture of this degree or more, we strongly subscribe to the opinion that surgical treatment offers the best prognosis.

The technic of operation together with management following surgery is described.

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SURGERY OF THE ACROMIOCLAVICULAR JOINT

JAMES W. TOURNEY

The two most common conditions affecting the acromioclavicular joint are *traumatic separation* and *degenerative arthritis*. Herein presented are two simple surgical procedures which deal with these situations in an effective manner when surgical treatment is indicated.

ACROMIOCLAVICULAR SEPARATIONS

These separations are common in active young adults inasmuch as anatomically the joint is not a strong one. I have known separations to occur without direct violence to the shoulder, simply due to strong muscle pull. The common cause is forcible depression of the shoulder, as so frequently seen on the football field.

There is great variation in the anatomy of this simple arthrodial joint, as Oppenheimer has pointed out. The shape of the bony outlines varies, as does the width of the joint space. The presence of an articular disk, complete or incomplete, is also variable.

This wide variation makes it important to take roentgenograms of both shoulders to aid in diagnosis. These are taken in the anteroposterior projection, with the patient in the standing position with a 5 pound weight in each hand. The film will then indicate the amount of subluxation or dislocation of the outer end of the clavicle.

The coracoclavicular ligament is formed in two parts, the anterior or trapezoid ligament, and the posterior or conoid ligament. It is usually believed that complete dislocation predicates a tear of the coracoclavicular ligaments, but Urist has shown that this is not necessarily the case. Therefore, we cannot be sure in every case whether rupture of these ligaments has taken place.

In my opinion, these separations should be treated surgically whenever gross anatomical subluxation or dislocation of the outer end of the clavicle has occurred, and this separation can be easily seen in the roentgenogram.

The mild cases can be treated simply by adhesive strapping, as Thordike and Quigley have shown.

Surgical Treatment of Acromioclavicular Separations.—The treatment we advocate for gross separations is operative fixation with Kirschner wires under general anesthesia. An incision, 10 cm. in length, is made parallel to the clavicle over the acromioclavicular joint, to expose 2 cm. of the clavicle, and the joint itself. Then the incision crosses the flat acromion to expose its lateral tip, so that two Kirschner wires may be

drilled from the tip of the acromion across the acromioclavicular joint, where they can be directly visualized, and thence extending into the marrow cavity of the clavicle for a distance of 5 cm. (Fig. 352). Heavy Kirschner wires, 90/1000 inch in diameter, of stainless steel should be used to obtain fixation and to prevent breakage. The wires are placed 1 cm. apart at the acromial tip, and are directed so as to enter the marrow cavity of the clavicle. When the wires have been correctly placed, they are cut off 0.5 cm. lateral to their point of entry into the tip of the acromion, and these protruding ends are turned with pliers at a 90 de-

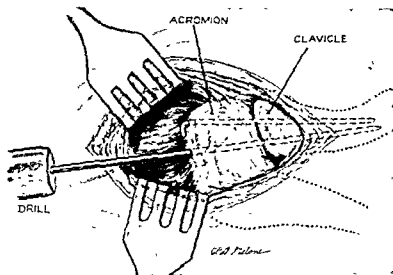


Fig. 352 — Fixation of acromioclavicular joint with Kirschner wires.

gree angle, so that the wires cannot migrate farther into the bone. The wound is then closed, the wires being completely buried. A sling is applied. Figures 353 and 354 show the appearance of an acromioclavicular separation before and after fixation.

The sling may be left off as soon as the patient is comfortable without it, usually in five days, and these patients may return to desk work in a week. Lifting is prohibited, but movements of the arm are encouraged up to 90 degrees.

Eight weeks after the wiring operation, the patient returns for removal of the wires through a small incision under local anesthesia.

Many metal fixation techniques have been described. Among them are the screw fixation of the clavicle to the coracoid of Bosworth, the use of one or two Kirschner wires by Gordon Murray, the use of threaded steel wires and a Velpeau by Phemister. Bloom has reported the Kirschner wire technic in a series of 20 patients. Caldwell has advised surgical arthrodesis of the acromioclavicular joint with internal fixation and bone chips.



Fig. 353—Complete acromioclavicular separation



Fig 354—Same case as shown in Figure 353 after fixation with two Kirschner wires

Late Cases —The wire fixation already described is very satisfactory, I believe, for early cases. If wiring is done later at a period of several weeks after the primary trauma, I do not know whether it would be successful. I would not be inclined to use this procedure in cases over two weeks old.

For the late cases either a major repair with fascia lata or resection of the dislocated outer end of the clavicle should be done. The latter is much simpler and preferable. This technic is described below under arthritis of the acromioclavicular joint.

Many complicated major repairs of acromioclavicular dislocations have been described in the literature beginning with Cadenat who utilized the posterior part of the coracoacromial ligament. Bunnell repaired both the coracoacromial ligaments and the acromioclavicular ligaments with a single long piece of fascia lata. Vargas has utilized the short head of the biceps. Watkins used braided silk. Campos modified Cadenat's technic. In my opinion the best and simplest operation of this type is a repair with fascia lata, simply tying the clavicle down to the coracoid with a loop of fascia lata which passes over the clavicle and under the coracoid and which is sutured to itself with multiple silk sutures.

Many forms of apparatus have been described for complete ruptures. Urist uses a plaster body jacket extending to the ilium, with pressure exerted over the outer end of the clavicle with elastic traction. In his article he gives a comprehensive review of various forms of treatment. Anderson and Burgess developed a "suspension-hammock clavicle splint." In my opinion, cumbersome external splints are much more uncomfortable for the patient than the wiring procedure which affords internal fixation without the use of external apparatus.

ARTHRITIS OF THE ACROMIOCLAVICULAR JOINT

Degenerative arthritic changes are common in the acromioclavicular joint, especially in heavily muscled laborers, in the middle-aged group.

The diagnosis is easy, as the patient usually has pain and tenderness over the joint itself, and the superficial subcutaneous situation of the joint facilitates examination. At times the pain is referred to the shoulder, and then this condition must be distinguished from *subacromial bursitis*, which is an even more common condition, frequently found in the same group of patients.

The roentgenologic findings of arthritis of the acromioclavicular joint are characteristic, namely spur formation and increased density of bone at the joint margins, together with enlargement of the capsule.

The primary treatment is conservative, consisting of physiotherapy, rest and salicylates. If such a regimen of therapy is unsuccessful then a trial of radiotherapy is indicated, as Oppenheimer has reported. If these

means fail or if the condition returns, then the surgical resection of the outer 2.5 cm. of the clavicle is indicated.

Partial Resection of the Clavicle.—This simple procedure has relieved the pain and disability of acromioclavicular arthritis as well as that of old neglected subluxations, as Gurd and Mumford described.

The operative technic is as follows: Through a 7 cm. incision above and parallel to the outer end of the clavicle, this bone is exposed from above subperiosteally, divided with double action bone shears at a

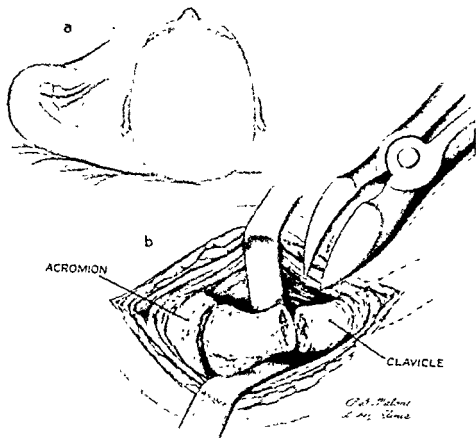


Fig 355.—Resection of lateral portion of clavicle.

point 2.5 cm. from the lateral end, and removed by dividing the acromioclavicular joint capsule with sharp dissection (Fig. 355). The wound is closed and a sling applied for a few days. After this active motion is encouraged.

The following case report concerns a painter who had severe pain in both acromioclavicular joints and who was so satisfied with the resection procedure on one side that he returned to have the other side done.

A 46 year old painter was admitted to the clinic with the presenting complaint of pain in the right shoulder region of thirteen months' duration aggravated by



Fig 356 —Acromioclavicular arthritis in 46 year old man who was relieved by resection



Fig 357 —Same case as shown in Figure 356 after resection.

his work. Rest, osteopathy, physiotherapy and radiotherapy had not relieved him. The pain was centered in the region of the acromioclavicular joint which was definitely tender. Roentgenograms of the right shoulder (Fig 356) showed

arthritic changes at the acromioclavicular joint. He was given a course of radiotherapy without relief. Two months after he entered the clinic the joint was injected with 10 cc. of 1 per cent procaine which had completely relieved his symptoms for a short period, thus proving the diagnosis. Two days later resection of the lateral 2.5 cm. of the right clavicle was performed. Figure 357 shows the postoperative appearance of the clavicle.

After an uneventful convalescence the patient returned to his work of painting one month after his operation and had no further symptoms in the right shoulder. However, six months after operation he began to have similar pain in the left shoulder, which did not yield to rest, salicylates or a course of radiotherapy. Accordingly, two months later he was admitted to the hospital and the outer end of the left clavicle was similarly resected. Six weeks later the patient returned to work free from symptoms.

CONCLUSIONS

For acromioclavicular separations requiring operation, fixation with two heavy Kirschner wires is recommended. Thus accurate reduction is secured and held without cumbersome and uncomfortable external fixation apparatus. With wire fixation the patient retains good use of his arm while the repair of ligaments is taking place.

For degenerative arthritis of the acromioclavicular joint which does not respond to physiotherapy or radiotherapy, we advocate resection of the outer 2.5 cm. of the clavicle. Prompt relief of pain is secured with no interference with function even in the laborer.

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ARTHROTOMY OF THE KNEE JOINT

FRANK L. SHIPP

Since the first successful arthrotomy of the knee joint was reported by Ambroise Paré in 1558, many and varied incisions have been devised and recommended. We have endeavored in recent years to select from these a minimum number to be used for routine exposures, with certain modifications as demanded by the individual problem at hand. Our intention in this paper is to review briefly the incisions so employed.

It seems almost unnecessary to point out that the factors determining the selection of an appropriate incision are adequate exposure of the affected parts and preservation of vital structures. Nevertheless, many incisions described in surgical textbooks appear to disregard these criteria.

The commonest pathologic conditions found have been internal derangement, fracture, degenerative arthritis, osteochondritis dissecans, popliteal cyst and tuberculosis. Only a few years ago, arthrotomy was often necessary for the drainage of purulent effusion. Since the advent of chemotherapy, joint infections demanding open drainage have been restricted almost entirely to cases of severe compound fracture. For such patients, we employ the usual anterior incisions (Fig. 358). These require no further explanation, other than to mention that primary closure is to be desired. Purulent effusions in acute hematogenous infections are usually controlled by repeated aspiration and the instillation of antibiotic media.

The surgical procedures for which these incisions have been most frequently used include: (1) exploration of the joint; (2) removal of loose bodies; (3) excision of a semilunar cartilage or of articular cartilage, (4) synovectomy; (5) popliteal dissection or posterior capsulotomy, and (6) arthrodesis.

MEDIAL OR LATERAL APPROACH

The incision described in 1931 by Timbrell Fisher has proved most satisfactory for the removal of either the medial or the lateral meniscus. Through the limited anterior portion of the incision it may be possible to perform the entire operation. In more difficult cases and, particularly, in the event of injury to the posterior horn, the incision is further developed to expose the entire meniscus. At the clinic, we do not believe, as did Fisher, that it should be used for the removal of loose bodies despite the fact that the anterior limb may be prolonged superiorly to open the suprapatellar pouch.

As described by Fisher, the approach is made with the knee flexed to 90 degrees (Fig 359). The curved skin incision begins at a point midway between the patellar ligament and the anterior border of the medial collateral ligament, opposite the upper extremity of the former. It ends just below the infraglenoid border of the tibial condyle and anterior to the collateral ligament. The infrapatellar branch of the saphenous nerve



Fig. 359 —Anterior incisions for drainage.

is avoided and preserved. The joint capsule and the synovial membrane are then opened through an incision parallel to and slightly posterior to that in the skin. The anteromedial compartment is now readily examined.

If no tear can be seen in the anterior portion of the meniscus or should its removal prove difficult, the opening in the synovial membrane is closed with a wet sponge. The curving skin incision is continued poste-

riorly and superiorly over the medial femoral condyle, and the flap of skin and subcutaneous tissue is reflected proximally.

At a point just posterior to the medial collateral ligament, the interrupted incision in the capsule is continued upward and backward to

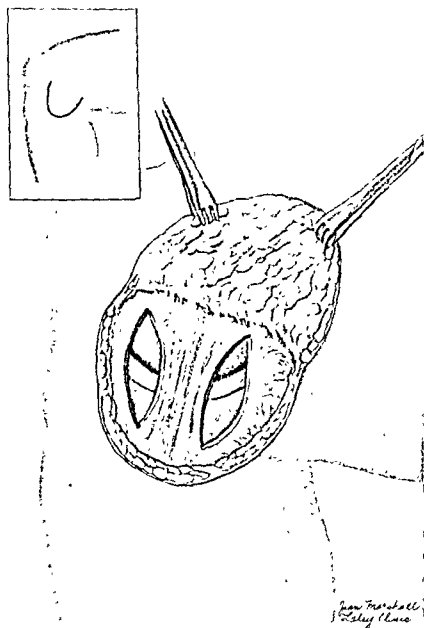


Fig 359.—Medial approach (Fisher).

reveal the posterior compartment. In this way an excellent view of the posterior horn of the meniscus is obtained. Complete removal can be achieved with a minimum of danger to either the posterior cruciate or the medial collateral ligament.

A similar incision may be employed for the removal of discoid, cystic

or other pathologic types of lateral meniscus. The intimate relation of the popliteus tendon to the cartilage should be kept in mind, however, as well as the fact that, unlike its fellow, this cartilage is in direct contact with the lateral collateral ligament. Particular care must be taken to safeguard these structures during the dissection.

When excision of the meniscus has been completed, the synovial membrane and the joint capsule are closed loosely as one layer with interrupted sutures of plain catgut, which allow any postoperative effusion to escape and to be more readily absorbed in the extra-articular tissues. The aponeurotic layer is closed snugly. Interrupted stainless steel wire sutures are used in the skin. A large pressure dressing is applied with at least the final elastic bandage running as a stocking from the toes to the thigh. Early, active quadriceps exercises also minimize postoperative effusion, satisfactory function is demanded before the patient is allowed to bear weight on the affected limb.

ANTERIOR APPROACH

For more complete exposure of the knee joint an ideal approach is that perfected by Coonse and Adams. It combines the advantages of maximal exposure and minimal retraction. Aside from allowing the anterior compartment to be opened widely, it provides an excellent approach for the treatment of fractures about the knee joint. Open reduction and internal fixation of supracondylar or T-fractures into the joint may be accomplished with little trauma. Furthermore, by opening the synovial membrane on either side of the femur, the bolts or screws may be inserted and subsequently excluded from the joint by closure of the membrane.

With the knee extended, the lower extremity of the quadriceps belly is identified (Fig. 360). Beginning superiorly over the lower muscle belly, a midline incision is made through the skin and subcutaneous tissue, passing either medially or laterally to skirt the patella and the patellar tendon. The overhanging flaps are dissected free from the quadriceps tendon and the patella. Beginning at its upper extremity, the tendon is split distally in the midline to within $\frac{1}{2}$ inch of the patella. The incision there bifurcates to pass on either side of the patella and the patellar tendon. A small blood vessel is usually encountered in the fat pad and requires ligation. The "tongue" of the inverted Y is turned downward to expose the anterior compartment (Fig. 361). Even wider exposure is gained by acute flexion of the knee.

To close the wound, the joint is first extended and the patellar flap is allowed to fall back into place. Identifying sutures placed opposite the upper extremity of the flap facilitate its accurate reapposition. If one wishes to lengthen the quadriceps tendon, the knee is only incompletely

extended and the vertical limb of the incision is thus increased in length. Heavy silk stay sutures are used to approximate the two leaves of the quadriceps tendon at their point of divergence. Interrupted sutures of chromic catgut in two layers complete the closure of the tendon and its

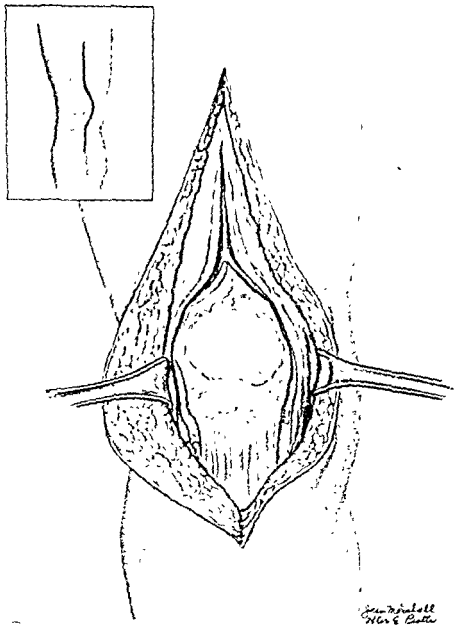


Fig. 300.—Anterior approach (Coonse and Adams).

expansion. The superficial fascia is closed independently. Stainless steel wire is used in the skin.

The usual pressure dressing may be reinforced with a posterior molded splint for greater comfort during the immediate postoperative period. Following arthrodesis, of course, complete immobilization in a plaster

cast or spica is necessary. Otherwise, early quadriceps exercises and active motion are encouraged. Quadriceps function is regained somewhat more slowly with this type of exposure, so that manipulation under

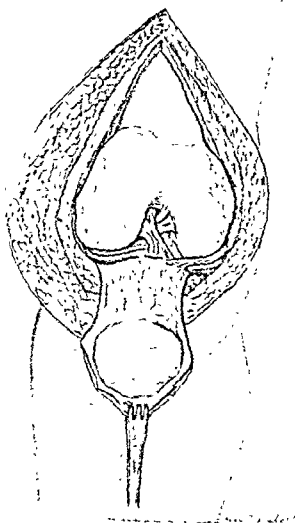


Fig 301 — Anterior approach (Coonse and Adams)

anesthesia is usually indicated ten to fourteen days after synovectomy or joint revision. Weight bearing may then be resumed. So secure is this type of closure that the knee may be acutely flexed without disruption of the sutures before the insertion of the subcutaneous layer.

This "general utility" incision has been employed satisfactorily for

many purposes, including removal of loose bodies, excision of semilunar cartilages, revision of the joint, reduction of fractures, synovectomy, arthrodesis and for the treatment of giant cell tumor.

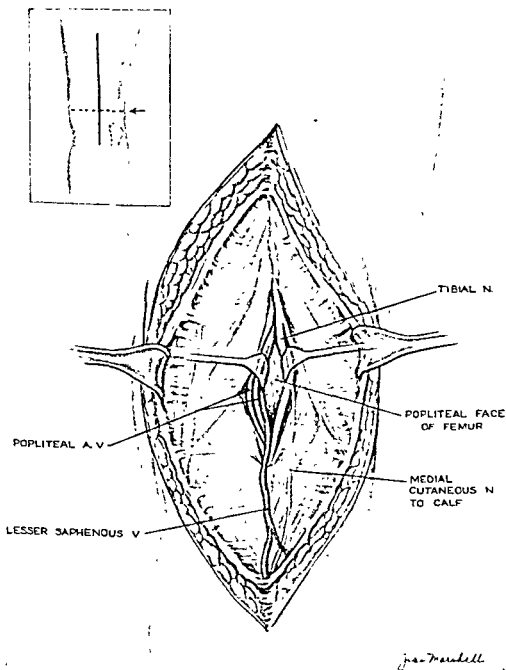


Fig. 362.—Posterior approach (Henry).

POSTERIOR APPROACH

In posterior capsulotomy, the excision of popliteal cysts or the removal of joint mice from the posterior compartment of the knee, the midline approach devised by Henry is used. With the patient prone,

the incision usually extends one-third below and two-thirds above the joint line, and is approximately 10 to 12 inches in length (Fig. 362). The level of the joint may be determined one fingerbreadth above the head of the fibula. Once the skin and subcutaneous fat have been divided from below upward, the lesser saphenous vein serves to identify the midline, overlying as it does the groove between the heads of the gastrocnemius. It usually lies superficially, but may be found occasionally under the deep fascia. Retracting the vein medially, the deep fascia is divided first at the lower extremity of the incision. The medial cutaneous nerve to the calf lies in the groove just under the fascia at this level. The division of the deep fascia is then carried proximally with care, for behind the knee joint the cutaneous nerve arises from the tibial, which latter may be damaged by a hasty finger or scalpel. Once the heads of the gastrocnemius have been identified, the popliteal neurovascular bundle can be found, separating the medial from the lateral hamstrings.

The tibial nerve and its muscular branches hide the popliteal vessels. It may be possible to displace the bundle *in toto* to one or the other side. If this proves difficult, the nerve and its branches are retracted laterally and the vessels medially, for the latter must enter the adductor canal at the upper extremity of the incision.

The popliteal face of the femur comes into view. The joint capsule may be exposed by flexing the knee without removing the retractors from the wound. On dividing the capsule and synovial membrane, the posterior compartment is laid open, exposing the posterior horns of the semilunar cartilages, the origin of the posterior cruciate ligaments and the posterior aspects of the femoral and tibial condyles.

Closure is effected in three layers, using interrupted sutures in the capsule, the deep fascia and the skin. With the knee extended, the flaps fall together easily, but closure of the fascia is best achieved by first inserting all its sutures and then tying them one by one. A pressure dressing is applied. No special after-care is necessary.

This approach may be modified when a popliteal cyst is to be excised, for the dome of the cyst may present itself immediately the deep fascia is divided. The cyst may then be exposed by blunt dissection. It will usually be found to arise from one of three sites: (1) the region of one of the tendons of the gastrocnemius, either medially or laterally; (2) occasionally from a bursa between the medial head and the tendon of the semimembranosus, or (3) from the posterior aspect of the joint itself. It should be remembered that such cysts are prone to extend much farther distally than one would suspect on physical examination. In any event, every effort is made to ligate the pedicle and to excise the sac completely.

SUMMARY

The approaches to the knee joint described above have been found on clinical trial to afford maximal visibility by direct access to the joint. Vital structures in the planes of dissection have been exposed deliberately and thus better protected. With minor modifications, these incisions have been employed for all of the routine procedures necessitating arthrotomy of the knee joint.

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TECHNIC OF SPINAL ANESTHESIA

URBAN H. EVERSOLE

The combination of flaccidity of skeletal musculature and contraction of the intestine makes spinal anesthesia very desirable for abdominal surgery. This is the paramount reason for using this type of anesthesia. It is, therefore, the choice when surgery is to be performed in the abdomen. The use of any other type of anesthesia must be for a special reason, usually because of a particular contraindication to spinal anesthesia. With technical improvements and a better understanding of the physiologic phenomena which accompany spinal anesthesia, together with more adequate means of nullifying or circumventing some of the undesirable side effects of this method of anesthesia, the number of contraindications is rapidly shrinking.

Spinal or subarachnoid anesthesia is the anesthesia produced by the injection of a relatively small amount of an anesthetic agent into the subarachnoid space. This agent acts directly on the nerve roots before they emerge from the dura. The extent of the body which is rendered anesthetic is dependent upon the distribution of the anesthetic agent in the subarachnoid space.

Although spinal anesthesia has been employed for surgery in all parts of the body, it is usually considered unsafe for operations above the level of the diaphragm. In recent years there has been a concerted effort on the part of anesthesiologists to devise techniques which limit spinal anesthesia more accurately to the area of the body in which the operation is to take place. In other words, instead of giving a single, relatively large dose of the spinal anesthetic agent to all patients and anesthetizing a large area of the body regardless of how limited the actual surgical procedure, the tendency is to try as far as possible to anesthetize only the area to be operated on. Aside from the quite obvious fact that this decreases the amount of anesthetic agent required and hence lessens the danger of toxic side effects, it seems reasonable to assume that there will be less effect on the autonomic nervous system and hence less circulatory and respiratory depression. Furthermore, there is evidence that postoperative neurologic complications may bear a direct relationship to the concentration of the anesthetic drug in the subarachnoid space, and that we may expect a lower incidence of these complications when lower concentrations of the anesthetic drug are used.

Types.—For practical purposes, spinal anesthesia may be classified as (1) "low spinal" when the spinal anesthesia does not extend above the umbilicus (tenth thoracic segment); (2) "medium spinal" when the

with every spinal anesthesia although technics are designed to keep as many of these factors constant as possible and to depend upon only one or two variables to obtain a given height of anesthesia

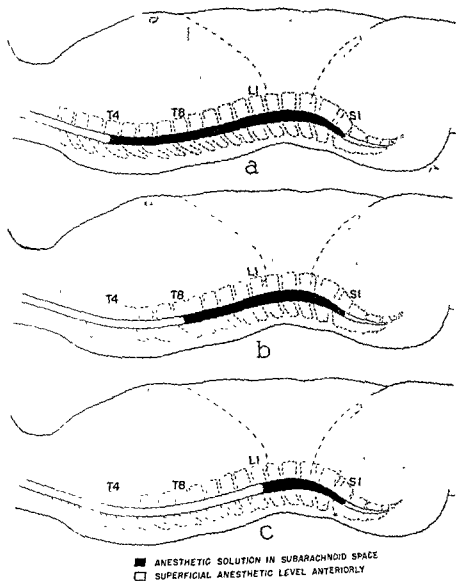


Fig. 363 —a, Anesthetic level necessary for complete abdominal exploration and upper abdominal surgery.

b, Anesthetic level necessary for lower abdominal surgery. Not adequate for complete abdominal exploration.

c, Anesthetic level necessary for perineal operations and surgery of the lower extremities.

A technic has been developed which, so far as possible, depends upon the ratio of the weight of the spinal anesthetic solution to that of the spinal fluid. This makes it possible for most of the factors influencing

the height of spinal anesthesia to be kept relatively constant and to utilize the force of gravity to determine the distribution of the anesthetic agent in the subarachnoid space. This is accomplished by adjusting the position of the patient during the early period following the injection of the agent into the subarachnoid space. It is to the discussion of such a technic that this paper will be largely confined.

Spinal anesthetic solutions are considered as: (1) hypobaric if they are lighter than spinal fluid; (2) isobaric if their specific gravity is

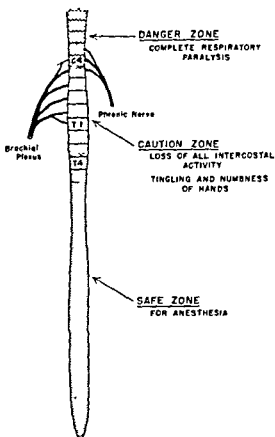


Fig. 304 —Diagrammatic section of spinal cord. Note proximity of fourth thoracic segment (level necessary for satisfactory upper abdominal surgery) to origin of phrenic nerve.

approximately the same as that of spinal fluid, and (3) hyperbaric if their specific gravity is greater than that of spinal fluid.

It is important that the anesthesiologist know in advance the relationship of the specific gravity of the anesthetic solution to that of the spinal fluid. It is obvious that when the solution is heavier than spinal fluid it will tend to flow downward and, therefore, if the patient is in the head down or Trendelenburg position during the early period following the injection of the agent, it will flow cephalad. Conversely, with the patient in the head up or Fowler position, it will have a tendency to flow caudad. If the solution is lighter than spinal fluid, the reverse

will be true, that is, the anesthetic solution will tend to travel in an upward direction. Hence, if it is desirable to confine the anesthesia to the lower part of the body, the patient should be in the head down position during the early period following the injection if a hypobaric solution is used. When the solution is isobaric, that is, approaching the specific gravity of spinal fluid, it tends to spread in both the cephalad and caudad directions at about an equal rate regardless of the position in which the patient is tilted. It is much more difficult to control the height of spinal anesthesia with an isobaric solution than it is with either hypobaric or hyperbaric solutions. As a rule, anesthesia tends to develop much more slowly with isobaric than with either hyperbaric or hypobaric solutions. Since there is considerable variation in the specific gravity of spinal fluid (1.001 to 1.009) a solution whose specific gravity is within this range may bear a different relationship to the spinal fluid from that anticipated. For this reason it is sometimes difficult to predict the height of spinal anesthesia with isobaric solutions. In our experience it is somewhat easier to control the height of spinal anesthesia with hyperbaric solutions than it is with hypobaric solutions.

The rate of injection is an important factor in determining the level of spinal anesthesia. In general, a rapid injection results in a higher level of spinal anesthesia. If the injection is made slowly with an isobaric solution, regardless of the position of the patient, the greatest concentration of the agent will be at the site of injection. With a hyperbaric or a hypobaric solution this is true only when the patient is level. The statement that a slow injection will result in maximal concentration at the lower levels or near the site of injection requires some qualification. With a hyperbaric solution, when there is considerable difference between the specific gravities of the spinal fluid and the solution injected, as with spinal anesthetic agents to which a considerable amount of dextrose has been added, a slow injection with the patient in the head down position may produce anesthesia much higher than a rapid injection. This is due to the fact that the heavier, somewhat syrupy solution trickles out of the end of the needle and runs down in the subarachnoid space as a mass without much mixing with the spinal fluid.

The volume of spinal anesthetic solution injected is also important in determining the level of anesthesia. The greater the volume of solution with a given amount of drug, the higher the level of anesthesia. Obviously, with a large volume of low concentration, the anesthesia may be quite high but not so intense, and the duration considerably less.

Barbotage is a factor which plays a considerable part in the height of spinal anesthesia. Barbotage may be defined as the mixing of the anesthetic solution with the spinal fluid as it is injected. Part of the agent is

injected, followed by withdrawal of some spinal fluid, and the process repeated several times.

If a large amount of spinal fluid is withdrawn prior to the injection of the anesthetic agent, the level of anesthesia will be higher. This may be due to a lowering of the spinal fluid pressure as well as to the diminishing of the volume of fluid into which the agent is injected.

Temperature plays a part in the height of spinal anesthesia. If a solution is warmer than spinal fluid when it is injected, it tends to spread more rapidly and thus produce higher levels of anesthesia earlier than with a colder solution.

The site of injection is a factor in determining the height of spinal anesthesia. If the injection is made in the lumbar area, however, the interspace employed is of minor importance. The truth of this statement becomes evident when we reconsider the distances that the agent must travel in the subarachnoid space, particularly for anesthesia for upper abdominal surgery. Often, too much emphasis is placed on the site of injection to the neglect of other more important factors.

Anesthetic Solution.—This discussion will be limited to the technic commonly employed at the Lahey Clinic for spinal anesthesia. For many years tetracaine (pontocaine) has been the agent of choice for spinal anesthesia. Pontocaine is approximately ten times the strength of procaine gram for gram, and in comparable anesthetic doses, that is, with a dose of pontocaine weighing one-tenth that of procaine, anesthesia will last approximately twice as long. Pontocaine is marketed in crystalline form (niphanoid) or as a 1 per cent solution in normal saline, in ampules containing 20 mg. of the drug. The specific gravity of a 1 per cent solution of pontocaine in normal saline is approximately 1.0069. This is very close to the average for spinal fluid which ranges from 1.001 to 1.009. Pontocaine in the 1 per cent solution or as niphanoid dissolved in saline solution or spinal fluid, for all practical purposes, may be considered isobaric and movement will, of course, be equal in both directions from the site of injection irrespective of the position in which the patient is lying. Obviously, the greatest concentration will be at the site of injection. If, however, the solution is modified by the addition of an innocuous substance with a fairly high specific gravity as compared with that of spinal fluid, an anesthetic solution is obtained that is heavy enough to allow the agent to be carried cephalad by gravity more or less as a mass. Ten per cent dextrose with a specific gravity of 1.039 is a satisfactory substance for this purpose.

The determination of dosage for spinal anesthesia in adults is shown in Table 1.

Technic.—When anesthesia is desired to the fourth thoracic segment,

the technic is as follows: The patient is turned to the lateral decubitus position and the head is elevated by means of an adjustable bar (sand-bags may be used for this purpose, also). This is to prevent the agent from progressing cephalad into the upper thoracic and cervical portions of the subarachnoid space. This bar also catches the lower shoulder of the patient, preventing him from sliding when the head of the table is lowered. The previously estimated dose of pontocaine is drawn into a 5 cc. syringe to which is added 10 per cent dextrose in a volume equivalent to one and one-half times that of the 1 per cent pontocaine. This solution is then thoroughly mixed. After the spinal puncture, the patient is placed in 10 degree Trendelenburg position, with the head elevated, and the 5 cc. syringe containing the anesthetic mixture is connected to the needle. The plunger is withdrawn slightly to make certain that the point of the needle is in the dural sac. The injection is made at the rate

TABLE 1

DETERMINATION OF DOSAGE OF PONTOCAINE FOR SPINAL ANESTHESIA IN ADULTS

	Ponto- caine, mg	10 Per cent Dextrose, cc	Position for Injection	Head Position
Upper abdomen	12-16	1.8-2.4	10 degree Tren- delenburg	Elevated
Lower abdomen	10-14	1.5-2.1	10 degree Tren- delenburg	Elevated
Perineum and lower ex- tremities	8-10	0.8-1.0 (1 cc of spinal fluid)	Level	Elevated

of about 0.25 cc. per second, after which the patient is turned supine and the level of anesthesia immediately checked. Notice of the time is made when the injection is started, since under no circumstances should the patient be left in the Trendelenburg position longer than one minute from the start of the injection without the height of anesthesia being checked. After the lapse of one minute after beginning the injection the table should be leveled. At this time the upper border of anesthesia will usually be to the sixth or seventh thoracic segment and will proceed up to the fourth or fifth segment in another one or two minutes. Should this not be the case, the table may again be changed to a 10 degree Trendelenburg position until the desired height is obtained. During all of these procedures care should be taken to see that the head is well elevated so that a marked upward slant of the cervical and upper thoracic portion of the spinal cord is maintained. Careful attention must be paid to the cephalad progress of the anesthesia; an undesirable height may

occasionally be obtained in less than one minute. Should this happen, the table is immediately tilted to a 5 degree Fowler position to prevent further cephalad flow of the anesthetic mixture. While this will not immediately lower the height of anesthesia, it will lessen its intensity and shorten its duration at the upper border. The respirations and blood pressure should be carefully watched during this early period in order that the anesthesiologist may be forewarned of any untoward reaction.

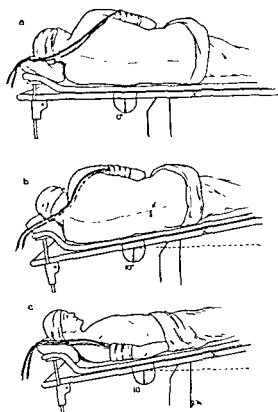


Fig 365 —Position for spinal anesthesia employing hyperbaric solution (pontocaine-dextrose)

- a, Position for spinal puncture.
- b, Position for injection of anesthetic solution
- c, Position for obtaining height of anesthesia

For operations for which steep Trendelenburg position is desired immediately, the technic is modified as follows: after one minute in 10 degree Trendelenburg position, the table is turned to 5 degree Fowler position for at least two minutes. Following this maneuver the patient may immediately be placed in the Trendelenburg position. Careful watch should be maintained for any degree of intercostal paralysis (Figs. 365, 366 and 367).

For lumbar operations such as nephrectomy or nephrostomy, the side to be operated on is placed down when the injection is made, on the

M - MATTRESS
 I - INTRODUCER (Moore)
 STN - SYRINGE, FINE TUBING
 MALLEABLE NEEDLE

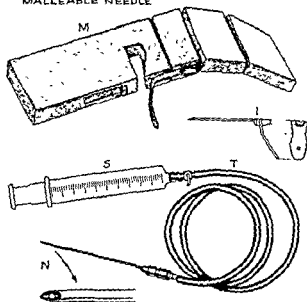


Fig 366 —Extra equipment for continuous spinal anesthesia (Lemmon)

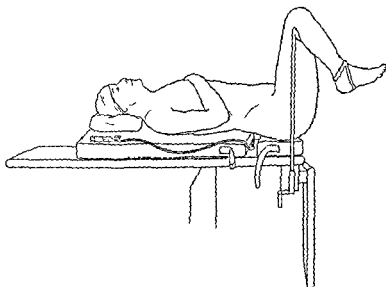


Fig 367 —Position of patient on mattress for perineal operation under continuous spinal anesthesia. Note needle in place and lower part of mattress removed

theory that the greater anesthesia will be on the dependent side since the anesthetic solution is heavier than spinal fluid.

For inguinal operations such as herniorrhaphy, the injection may be made with the patient level or in only slight Trendelenburg position for one minute.

A satisfactory technic for operations on the lower extremities, perineum, rectum, prostate or bladder is as follows. The spinal puncture is made in the fourth lumbar interspace. The solution consists of 1 cc (10 mg.) of 1 per cent pontocaine and 1 cc. of 10 per cent dextrose to which is added 1 cc. of spinal fluid withdrawn after the syringe has been connected to the needle in the subarachnoid space. The injection is made at about 0.5 cc. per second with the table level and the patient's head elevated. Following the injection, the patient is placed on his back for two or three minutes and anesthesia tested. With this technic anesthesia is usually confined to below the twelfth thoracic segment, which is satisfactory for operations on the anus, rectum or lower urinary tract. The patient may safely be turned on his abdomen or placed in the lithotomy position immediately after the proper height of anesthesia has developed.

Various changes in these details may be made if desired. When using a hyperbaric solution for spinal anesthesia, however, care must always be taken to see that the head is kept well elevated and the patient is not left too long in a downward slant.

The dose of an anesthetic agent in any given case is a matter of judgment. Table 1 for dosage of pontocaine, expressed in milligrams for adults, has proved valuable. These doses are meant as suggestions and should be considered starting points for the anesthesiologist's judgment.

CONTINUOUS SPINAL ANESTHESIA

The introduction of the continuous technic for spinal anesthesia by Lemmon has greatly widened the field of usefulness of this method of anesthesia. Not only has this technic eliminated one of the greatest objections to spinal anesthesia, namely that the operation frequently outlasted the anesthesia necessitating the use of supplementary agents and methods which were often much less satisfactory, but it has enabled us to tailor the anesthetic dose to the surgical requirements more accurately. In fact, this technic has been almost as useful in permitting us to use very small doses of anesthetics for short procedures as it has in enabling us to use larger doses over a longer period of time for the more extensive procedures.

In addition to the materials required for ordinary spinal anesthesia, continuous spinal anesthesia requires special needles made of malleable metal to allow for considerable bending without danger of breaking. Furthermore, a rubber covered mattress, 5 inches thick, 18 inches wide

and 6 feet long, with a cut out part 7 inches in length which comes under the lumbar area when the patient is supine, is desirable. The mattress is divided in half so that the portion which supports the lower extremities may be detached for perineal operations. In addition, it is necessary to have approximately 30 inches of fine caliber rubber tubing with Luer-Lok connection at each end for attaching the spinal needle and the syringe containing the spinal anesthetic solution (Figs. 368 and 369).

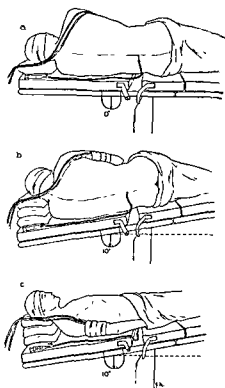


Fig 368 — Position for induction of continuous spinal anesthesia (Lemmon)

a, Patient in left lateral decubitus position, spinal needle in place and syringe and tubing connected

b, Position of patient for injection of hypobaric solution (pontocaine-dextrose mixture) for continuous spinal anesthesia

c, Position of patient for obtaining height of spinal anesthesia by continuous method.

Technic.—While there are many variations of the original continuous spinal technic as described by Lemmon, this discussion will be confined to only one technic, employing pontocaine and dextrose. It is the technic that has been employed at this clinic for several years.

Spinal puncture with the malleable needles used for continuous spinal anesthesia is greatly facilitated by the use of a special introducer (Moore). This type of introducer is so designed that it can be removed

after the needle is in place without dislodging the needle. The reservoir of spinal anesthetic solution for continuous spinal anesthesia is prepared as follows: 3 cc. of 1 per cent pontocaine, 6 cc. of 10 per cent dextrose and 1 cc. of normal saline are drawn into a 10 cc. syringe and thoroughly mixed. This makes a total volume of 10 cc. and is a 0.3 per cent solution of pontocaine. Each cubic centimeter of the mixture contains 3 mg. of pontocaine. The tubing is filled with the mixture before it is attached to the spinal needle. The initial dose, 9 to 15 mg. (3 to 5 cc.), is injected slowly (0.25 cc. per second) into the third lumbar interspace while the patient is still lying on his side. Prior to starting the injection the table is turned to the head down position, 10 degrees from the horizontal, with the patient's head elevated to raise the cervical and upper thoracic spine. Immediately following the injection the patient is turned on his back and the height of anesthesia should be tested almost constantly until the desired level is obtained. The level of anesthesia usually will be to the nipple line (fourth thoracic segment) in one to two minutes. The patient should not be left in the head down position longer than one minute unless tests show the anesthetic level to be lower than the xiphoid process (sixth thoracic segment). An accurate determination of the height of anesthesia should be obtained repeatedly as long as the patient is in the head down position and for several minutes thereafter (Fig. 368).

When pontocaine is the anesthetic drug used it is rarely necessary to administer secondary doses of the anesthetic mixture more frequently than every one and one-half hours.

The technic for subsequent doses of pontocaine-dextrose for spinal anesthesia by the continuous method is as follows: at the end of one hour the stopcock on the Luer-Lok connection to the syringe is opened and the spinal fluid is withdrawn in an amount sufficient to equal one-half that remaining in the syringe and tubing after the initial injection. The anesthetic mixture will now contain 2 mg. of pontocaine per cubic centimeter instead of the original 3 mg. At the end of one and one-half hours or when there is evidence that the initial dose is wearing off, a subsequent dose is administered by the following technics. If the patient is level the second dose should be approximately one-half the original dose. It is given in the following manner: 0.5 cc. of spinal fluid is withdrawn into the tube and 1 cc. of the mixture is injected. This process is repeated until the desired dose has been administered. If the patient is in Trendelenburg position, the second dose should not exceed one-fourth to one-third the original dose and should be administered slowly without barbotage.

A notable modification of Lemonon's technic for continuous spinal anesthesia is that made by Tuohy. By this technic a number 3½ ureteral catheter is inserted into the subarachnoid space through a 16 gauge

Huber needle, which is withdrawn, leaving the catheter in place. The catheter can be directed either cephalad or caudad by the position of the opening in the end of the Huber needle. This technic has the advantage of obviating the need for a special mattress and is particularly useful in operations for which the patient is not on his back.

Saklad has further modified the technic for continuous spinal anesthesia. He passes the number 3½ ureteral catheter cephalad into the subarachnoid space until the tip lies opposite or near the nerve roots supplying the area where the maximum intensity of the anesthesia is desired. For upper abdominal surgery this would mean that the catheter should be advanced cephalad in the subarachnoid space for 20 to 25 cm. When low concentration of the anesthetic solution (0.05 to 0.1 per cent pontocaine or 0.5 to 1.0 per cent procaine) is used it is possible to obtain spinal anesthesia with a surprisingly small total dose of the drug. Satisfactory anesthesia for upper abdominal surgery has been obtained by this method with as little as 2 to 3 mg. of pontocaine. With this technic anesthesia is usually segmental in distribution and may be confined almost entirely to the abdomen with little if any anesthesia in the lower extremities.

THE MANAGEMENT OF THE PATIENT UNDER SPINAL ANESTHESIA

The management and supervision of the patient under spinal anesthesia is extremely important. No spinal anesthesia is finished upon completion of the spinal puncture and injection of the anesthetic agent. The patient should be under the constant care and observation of a physician acquainted with all the possible complications of spinal anesthesia and he should have adequate facilities to control or correct any untoward condition which may arise.

Many of the difficulties encountered during the course of spinal anesthesia are associated with improper distribution of the spinal anesthetic agent in the subarachnoid space. The anesthetic agent may not reach a level sufficiently high to produce adequate anesthesia for muscular relaxation and to eliminate all painful stimuli. Sometimes pain from the operative site may be referred to an area not under the control of the spinal anesthetic agent and thus be a source of physical distress to the patient. When such a situation arises, a supplementary form of anesthesia must be used. Pentothal sodium intravenously or cyclopropane gas is usually quite satisfactory as a supplementary agent.

With a single dose of spinal anesthetic agent, too often the operation outlasts the anesthesia. This condition, of course, necessitates the use of supplementary general anesthesia. The transition is more easily accomplished if the supplementary agent is started before the patient begins to feel pain or there is any loss of muscular relaxation. Warning signs, other than the elapse of time, that the anesthesia may be about

to wear off are increased restlessness, sweating, rise in blood pressure, or the patient may complain of a vague feeling of discomfort, without any actual pain, at the site of the operation

The intravenous administration of curare has proved to be of great value as an adjuvant to inadequate spinal anesthesia when muscular relaxation is desired. This drug, of course, is not an anesthetic and is used in combination with other supplementary agents, such as cyclopropane or pentothal sodium.

Respiratory Impairment.—Serious impairment of respiration may be a complication of spinal anesthesia. This is particularly true if this form of anesthesia is employed for upper abdominal surgery. It is of utmost importance that respiratory impairment should be recognized immediately. If the motor divisions of the thoracic nerves are anesthetized as

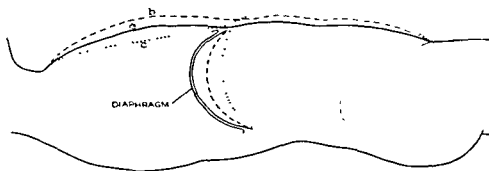


Fig 369—Position of chest and abdomen under spinal anesthesia

a, Normal position at end of expiration

b, Position at end of normal inspiration.

c, Position at end of inspiration, with complete intercostal paralysis

high as the fourth thoracic segment (the height necessary for satisfactory upper abdominal surgery), the intercostal muscles below this level will be inactive, and the elevation of the ribs and expansion of the chest on inspiration will be brought about by the pull of the four upper intercostal muscles. If the agent continues to progress cephalad, the remaining intercostal muscles become inactive and the chest no longer expands with inspiration. If the patient is asked to take a deep breath at this time, only diaphragmatic breathing can be observed. The chest will remain entirely motionless or the intercostal spaces may even retract on inspiration. This is one of the earliest and most important warning signs that the anesthesia is going too high. At this time the patient may also complain of numbness or tingling in the hands. This is, of course, due to involvement of the roots of the brachial plexus. If the agent continues until it reaches the level of the fourth cervical nerve root, the diaphragm becomes paralyzed and complete respiratory arrest follows.

Usually, before respiration becomes completely arrested the conscious patient will attempt to increase the size of the chest cavity by using the *accessory muscles of respiration*. This can be detected by observing the patient's neck for increased activity of the sternomastoid and platysma muscles. The patient may also lose his voice and become quite apprehensive (Fig 369).

If unrelieved, this condition will lead to anoxia, circulatory collapse and death. The treatment is obvious. It consists of the administration of oxygen with some mechanical assistance to inspiration if there is inadequate respiratory exchange. This assistance is absolutely essential if there is *complete respiratory arrest*. It can best be accomplished by administering oxygen from a gas machine and exerting rhythmic pressure on the rubber breathing bag coincidental with each attempt at inspiration on the part of the patient. If there is no attempt at inspiration, the lungs should be inflated by pressure on the breathing bag at a rate of about sixteen times a minute. Obviously, the establishment of a free and unobstructed airway is imperative. Respiratory stimulants are not indicated and pressor drugs should be used at this stage only if indicated because of secondary circulatory depression. If immediate and adequate treatment is instituted, this condition need cause no great alarm and usually secondary circulatory depression does not occur. A period of respiratory depression rarely lasts longer than twenty or thirty minutes. On the other hand, without immediate and adequate treatment, this complication will result in a fatality.

Circulatory Depressions.—Rather profound circulatory depression may accompany spinal anesthesia. Circulatory depression is much more common with high spinal anesthesia than when the anesthesia is confined to the lower part of the abdomen. This depression may be further enhanced by surgical manipulation in the abdomen. Circulatory depression will surely follow unrelieved respiratory depression. The routine use of a pressor drug (50 to 75 mg. of ephedrine or 20 mg. of desoxyephedrine) intramuscularly a few minutes before the induction of spinal anesthesia is a valuable safeguard against circulatory depression.

Many pressor drugs have been employed successfully to combat blood pressure falls which occur in spite of prophylactic intramuscular administration of ephedrine or desoxyephedrine. Epinephrine is an effective blood-pressure raising drug. This drug, however, is rather transient in effect and may seriously disturb cardiac rhythm. Furthermore, there may be a compensatory fall in blood pressure following the transient rise. Ephedrine given intramuscularly is usually effective but it is quite slow in action and it is for this reason that if this agent is used alone to treat a serious fall in blood pressure, 0.25 to 0.5 cc. should be given intravenously. An extract of the posterior pituitary gland (pitressin) is effective in raising blood pressure and is usually quite prompt in action.

The fact that this drug may constrict the coronary arteries and the danger of a decrease in blood supply to the heart must be borne in mind. The danger may, perhaps, be minimized if the pitressin is combined with ephedrine. A combination of 5 units of pitressin (0.25 cc.) and 25 mg. of ephedrine (0.5 cc.) intramuscularly has proved satisfactory for the treatment of blood pressure falls due to spinal anesthesia. The response is usually prompt and well sustained. One-fourth to one-third of this dose may be given intravenously in the presence of a severe fall in blood pressure. The heart rate and rhythm usually are changed very little if

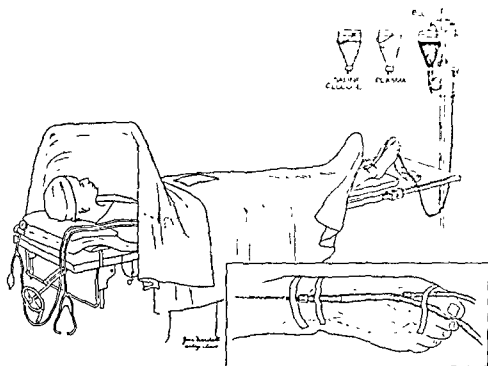


Fig 370—Patient ready for operation under spinal anesthesia. Note blood pressure cuff in place and constant intravenous drip with needle in saphenous vein. Supportive fluid and supplementary intravenous agents available.

any, with this combination. Neosynephrin is an effective drug for raising the blood pressure. In single doses, however, it is quite transient in its action. It usually does not disturb cardiac rhythm although it may slow the pulse considerably. A continuous drip of a very dilute solution of neosynephrin (0.5 cc. or 5 mg.) in 500 cc. of normal saline solution is effective as a means of maintaining blood pressure under spinal anesthesia. This method allows for very fine control and permits rapid administration in the event of an acute fall in blood pressure. It must always be borne in mind when using pressor drugs that they must never be substituted for fluid and blood in the presence of shock resulting from blood loss or trauma.

Nausea, retching and vomiting are frequent, annoying complications of spinal anesthesia. If these complications are more than a momentary disturbance, the patient should be made unconscious by the use of a supplementary agent such as cyclopropane or pentothal sodium. This enables the surgeon to continue the operative procedure without interruption and relieves the patient of an uncomfortable and disturbing experience. The danger of vomitus being aspirated into the trachea should always be kept in mind when a general anesthetic agent is administered for the relief of nausea and vomiting.

There is no reason why any patient who objects to being awake during an operation cannot have the comfort of being asleep and at the same time have the advantages of spinal anesthesia. Frequently, an additional dose of morphine intravenously and the intravenous administration of 1 to 3 grains of nembutal after the patient is in the operating room will allay apprehension and nervousness.

If an intravenous needle is placed in the great saphenous vein near the medial malleolus and a slow drip of fluid maintained throughout an operative procedure, a route is immediately available for the administration of supplementary anesthetic agents or for the administration of supportive drugs and fluid. The use of the saphenous vein has the advantage of removing the intravenous apparatus to a point where it will not interfere with any type of surgery except that on the lower extremities. If the intravenous drip is not started until after the spinal anesthetic is given, the patient will have no discomfort from the insertion of the needle, and the dilatation of the veins which follows spinal anesthesia facilitates its insertion (Fig. 370).

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TECHNIC OF ENDOTRACHEAL ANESTHESIA

MORRIS J. NICHOLSON

The maintenance of a free airway should always be the first consideration in the administration of a general anesthetic. The danger of complete respiratory obstruction has for ages been recognized by laymen and physicians alike.² But the cumulative effects of partial respiratory obstruction have often been overlooked and it is not unlikely that many surgical difficulties, postoperative complications and even fatalities attributed to the operation or the anesthetic agent have been primarily due to the anesthetist's failure to provide an unobstructed airway. Because the endotracheal method of inducing anesthesia provides an assured airway at all times and, in addition, makes it possible to administer an anesthetic without a face mask, its popularity and use have steadily increased. Endotracheal anesthesia is indicated for head and neck operations, especially those of the mouth and nose; for certain thoracic and abdominal operations and for operations in which respiratory difficulties exist or may be encountered.

In this paper a detailed description of the methods by which endotracheal intubation can be accomplished will be given and along with this, a discussion of the equipment and anesthetic agents used will be included.

EQUIPMENT

The essential equipment for endotracheal anesthesia consists of a laryngoscope and any one of several types of endotracheal tubes.

Accessory equipment, not absolutely essential but often quite helpful, is as follows: a small lead plate to protect the patient's teeth, atomizers, straight and curved types, inflatable cuffs, a long rigid suction tube, urethral catheters sizes 14 and 16 French for the aspiration of mucus and debris from the endotracheal tube, metal adapters to couple the endotracheal tube to the anesthetic machine and a nonirritating lubricant with a melting point below the body temperature (Figs. 371 and 372). Helpful but not nearly as essential as the above-mentioned equipment are intubation forceps, flexible metal connectors, several types of Ayres tubes and various sizes and shapes of metal endotracheal adapters.

Laryngoscopes, now in common use, fall into one of two groups according to their shape, the U and the L type (Fig. 373). The blade of

L type laryngoscope forms an angle of 90 degrees or less with the handle. The blade of the U type laryngoscope is joined by one part of the handle to form a right angle and the U shape is completed by the second part of the handle joining the first at a right angle. The shape of the U type

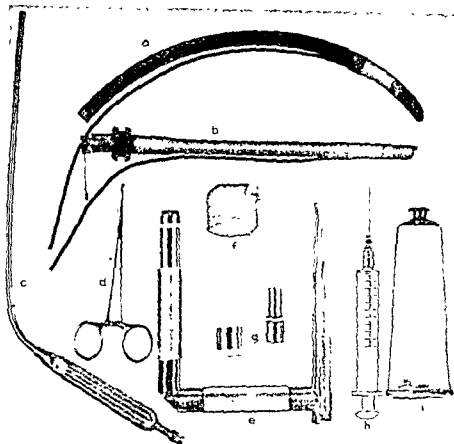


Fig. 371—Equipment commonly used for endotracheal intubation *a*, Rubber endotracheal tube (Magill) with cuff *b*, Flexible metal endotracheal tube (Woodbridge) with cuff, *c*, Metal suction tip *d*, Hemostat used to clamp tube after cuff has been inflated *e*, "U" shaped laryngoscope (Eversole) *f*, Lead plate to protect teeth *g*, Universal metal adapter *h*, Syringe for inflating cuff *i*, Lubricant

laryngoscope is such that effective lifting motions required for exposure of the larynx can better be applied to the blade. When this lifting motion is attempted with the L shaped instrument there is a strong tendency to use leverage and damage the teeth by using them as a fulcrum.

The Eversole laryngoscope shown in Fig 373 combines most of the

advantages of the laryngoscope popularized by Jackson,⁵ which are a narrow blade, U shape, and a removable slide which will occlude the channel so as to prevent the tongue or a single tooth from bulging into the lumen of the instrument and obstructing the view. In addition the Eversole laryngoscope has a battery and a switch in the handle so that a separate battery box and light cord are not needed. This gives a compact instrument which is ready to be used at any time. Laryngeal exposure

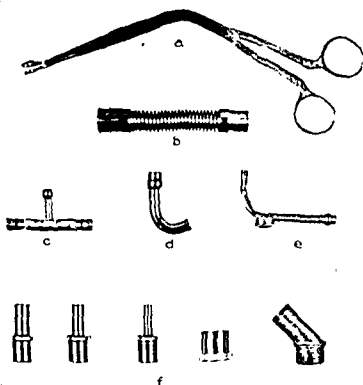


Fig 372—Equipment occasionally used for endotracheal anesthesia. *a*, Magill endotracheal forceps. *b*, Flexible metal connecting piece. *c*, Ayre's tube. *d*, Magill metal elbow. *e*, Angular finger valve for suction or insufflation. *f*, Variety of metal endotracheal adapters.

has been accomplished on children as well as adults with this instrument and, in our hands at least, these exposures are accomplished more readily and with less trauma than when some of the specially modified laryngoscopes which are said to have special features of design are used.

ENDOTRACHEAL TUBES

Figure 374 shows a variety of endotracheal tubes now in general use: (1) Woodbridge (spiral metal wire with metal tip and hilt covered with Penrose rubber tubing); (2) spiral metal wire embedded in rubber; (3) silk-woven; (4) plastic (portex); (5) rubber (Magill), and (5, *a*) rubber (Magill) with built-in cuff.

Woodbridge Tube.—The spiral wire endotracheal tube designed by Flagg¹ and modified by Woodbridge² is widely accepted. It consists of a metal hilt and a small metal tip with coiled wire connecting the tube. These tubes are held straight and rigid by means of a hollow stilet which facilitates their handling during intubation. They are strong and flexible without a tendency to obstruct by kinking or compression. Because of

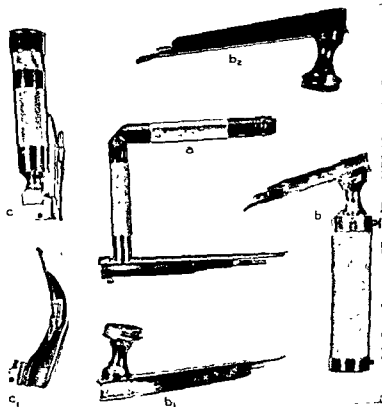


Fig 373 —Laryngoscopes in common use *a*, Eversole "U" shaped *b*, Guedel "L" shaped with small, medium (*b*₁) and large (*b*₂) blades *c*, Folding laryngoscope with Miller infant blade attached, *c*₁, Macintosh blade which also may be attached to a small handle (Foregger Company.)

the strong material used in their construction, the walls can be thin so that the internal diameter or breathing space is greatest in proportion to their external diameter. Penrose tubing is used to cover these spiral wire tubes to prevent the mucous membrane from being caught in the coils, and also to make them air-tight. The metal hilt provides a place for the attachment of an adapter in order to connect the patient to the anesthetic supply. It also provides a place for the attachment of a rub-

ber spool which fits between the patient's teeth and protects them from injury when closed on the metal. These tubes are manufactured in two lengths. The short tube can be used beneath the anesthetic mask or with an adapter and an inflatable cuff to provide a closed system. The

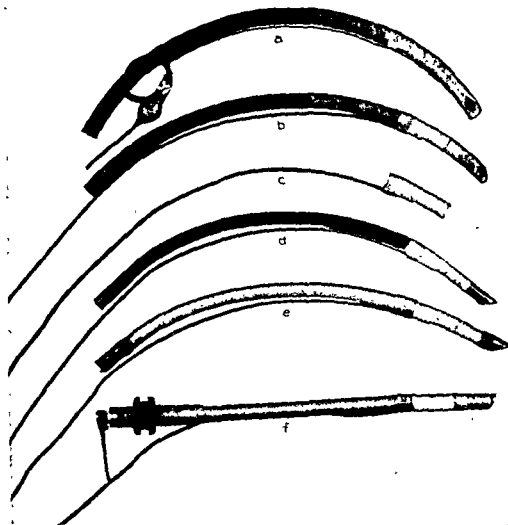


Fig. 374 —Endotracheal tubes now in common use. *a*, Magill—rubber with built-in cuff. *b*, Magill—rubber with inflatable cuff. *c*, Portex—plastic with inflatable cuff. *d*, Woven silk with inflatable cuff. *e*, Spiral wire embedded in rubber with inflatable cuff. *f*, Woodbridge (spiral wire with metal tip and hilt covered with Penrose tubing and inflatable cuff attached).

long tube is designed for use with an inflatable cuff and an adapter when it is desirable to remove as much as possible of the anesthetic equipment from the immediate region of the patient's mouth.

Plastic (Portex)*.—Plastic (portex) tubes have found a large field of usefulness (Fig. 375). They are relatively inexpensive, durable and are

* Manufactured by Portland Plastics, Ltd, Dover, Kent, England.

manufactured in practically every size one could possibly need. They have a relatively large bore but their walls are very resistant to kinking, and this makes them particularly valuable in the small sizes for pediatric anesthesia. They may be used repeatedly, with inflatable cuffs attached, to provide an air-tight system as they almost never develop a leak in their walls. Once the tube is introduced into the trachea and it reaches body temperature it becomes more flexible and molds itself to fit the natural configuration of the airway. When they are used, care must always be exercised, as it must with all endotracheal tubes that do not have metal hilts, to prevent their becoming obstructed by the closure of the patient's teeth.

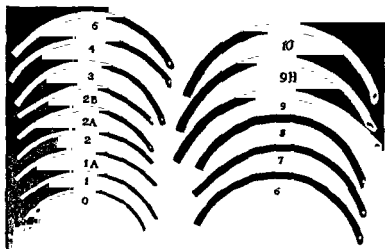


Fig. 375.—Portex (plastic) endotracheal tubes; note fifteen different sizes.

Rubber.—Rubber tubes used for endotracheal anesthesia are generally associated with the name of Magill⁶ who popularized their use in England. These tubes are now made of a special mineralized rubber designed to remain resilient in spite of their thin walls. They are curved to conform to the nasal fossa, but they are equally suitable for nasal or oral intubation. They may be obtained with either thick or thin walls. The thick-walled tubes are used for oral intubation and the thin-walled variety has been designed for nasotracheal intubation. These tubes should not exceed in length twice the distance from the lobe of the ear to the ala of the nose in order to prevent their being introduced into the right main stem bronchus. They are easy to clean, can be sterilized by boiling and are quite durable. One end is beveled so that the point is to the right when viewed from its concave aspect. When these tubes are fitted with an inflatable cuff of the Guedel-Waters⁷ type and passed

through the nose, a closed system can be provided for surgery in the mouth. More recently, a specially designed Magill tube with a built-in inflatable cuff has been manufactured, as shown in Figure 374, for this particular purpose. Once these tubes are in place and the cuff inflated, the aspiration of blood and mucus is prevented. One disadvantage to the use of these tubes is that they may become obstructed either by kinking when the head is rotated or flexed to an exaggerated degree, or by closure of the patient's teeth upon them when they are used by the orotracheal method. The aspiration of mucus, blood or debris from the tracheobronchial tree is not as readily carried out through them as through the spiral wire tubes, and a nasal hemorrhage is not uncommonly associated with their passage through the nose.

Woven Silk.—Woven silk endotracheal tubes, formerly manufactured in France and now almost impossible to obtain in America, are somewhat stiff-walled but flexible, with a smooth outer and a rough inner surface. These tubes cannot be sterilized by boiling because of the shellac used in their construction, but must be soaked in an antiseptic solution. They may be fitted with an inflatable cuff and used for oral or nasal intubation.

Spiral Wire.—Tubes formed of spiral wire embedded in rubber possess many of the good qualities of the ordinary spiral wire tube covered with Penrose tubing. However, they also lack a metal hilt, as do the plastic, rubber and woven silk catheters, for the attachment of an adapter or a rubber spool so as to connect them to the anesthetic supply and to prevent the patient from biting them.

ANESTHESIA

Endotracheal intubation may be readily accomplished under topical anesthesia and this method of intubation is indicated for patients suffering from suppurative pulmonary disease. If a general anesthetic is used for intubation, the induction period is often associated with an accumulation of fluid in the air passages large enough to dangerously hamper respiratory exchange. When the intubation has been done under topical anesthesia, before induction of a general anesthesia is started, this fluid can be removed as it accumulates by aspirating through the tube. Patients with partial respiratory obstruction from intrathoracic goiter, cancer of the thyroid, unilateral or bilateral paralysis of the recurrent laryngeal nerve and those with cardiac disease who show markedly reduced vital capacities constitute another group for whom endotracheal intubation under topical anesthesia is indicated as none of them can well withstand even the slight respiratory obstruction so often associated with the induction of general anesthesia.

Adequate preliminary medication and gaining of the patient's confidence are prerequisites to successful intubation under topical anesthesia.

After anesthetizing the vestibule of the nose by spraying it with 10 per cent cocaine or 1 per cent pontocaine hydrochloride, a curved Rowbotham atomizer (Fig. 376) may be passed through the nasal cavity so as to anesthetize the nasopharynx (Figs 377 and 378). With the atomizer in place, the epiglottis and larynx are anesthetized by coordinating the

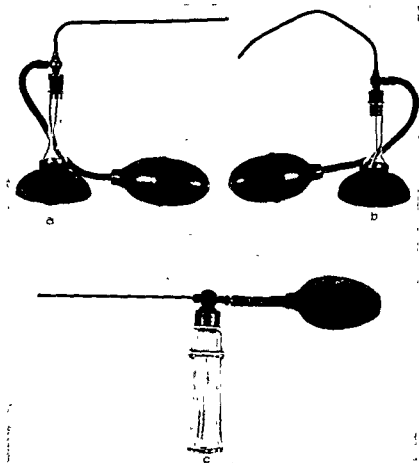


Fig 376—Atomizers *a*, Straight Rowbotham *b*, Curved Rowbotham *c*, Straight DeVilbiss.

spraying with the patient's inspirations. Any atomizer may be used, but the Rowbotham is especially designed for this purpose. Blind nasotracheal intubation may be carried out as described later, or the larynx may be exposed with the laryngoscope, its anesthetization completed with a long, straight Rowbotham* or DeVilbiss† atomizer (Fig. 376)

* Manufactured by Frank Rogers, 1 Beaumont Street, London, England.

† Manufactured by the DeVilbiss Company, Toledo, Ohio—Number 151 Physicians Atomizer.

and the intubation performed under direct vision. The topical application of cocaine to the superior laryngeal nerves at the piriform sinus

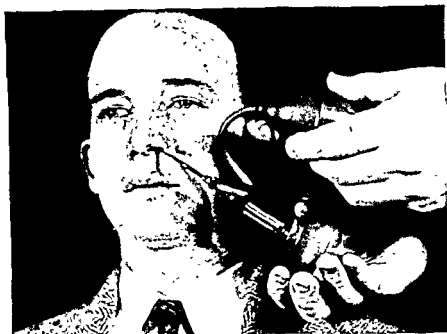


Fig 377.—Position of operator when curved Rowbotham atomizer is used to anesthetize the nasopharynx.



Fig 378 —Location of the tip of the curved Rowbotham atomizer in the nasopharynx as shown by lateral roentgenogram of skull.

with the curved throat forceps is an additional aid in producing good anesthesia. If bronchoscopy is to be done before the intubation, 5 cc. of a 2 per cent cocaine solution dripped into the larynx from above or

30 mg. of pontocaine hydrochloride in 9 cc. of physiologic saline solution injected into the trachea through the cricothyroid membrane provides adequate anesthesia of the tracheobronchial tree for this procedure.⁴

When general anesthesia is desired for endotracheal intubation, it may be produced by ethylene, cyclopropane or ether, singly or in combination with avertin, nitrous oxide or intravenous sodium pentothal. The routine use of 10 per cent cocaine topically to the larynx and trachea is helpful regardless of which one of the general anesthetic agents is to be employed. This added topical anesthesia decreases much of the coughing or apnea seen after stimulation of the larynx or trachea. Skillful induction is more important than the agent used or the actual intubation itself. Intubation is greatly facilitated if the depth of anesthesia is such that pharyngeal and laryngeal reflexes are abolished and the cords abducted. When these conditions exist, intubation may be carried out before sensation reaches the larynx and the muscles lose their relaxation. This does not mean that deep anesthesia is required but it does presuppose that relaxation of the jaw will be obtained and that the entire act of intubation will be executed with deft, premeditated accuracy.

INTUBATION

Nasotracheal Method.—Endotracheal intubation may be performed either through the nose or through the mouth. The nasal route is indicated for certain oral operations, because the mouth is left free, and for certain plastic procedures about the face, especially the lower lip. This method is valuable for patients with ankylosed jaws when orotracheal intubation is impossible.

The blind method of nasotracheal intubation is frequently successful without recourse to the laryngoscope, and is worth while attempting if the proper conditions exist. The nose should be examined beforehand in attempt to determine which nostril offers less obstruction to the passage of the tube. The endotracheal tube should never be forced through the nares when resistance is met as this almost inevitably results in nasal hemorrhage which complicates the entire procedure. The head should have the same relation to the neck and trunk in the recumbent as in the erect position, and a pillow is generally required below the occiput. Magill described the ideal position of the head as the one a man unconsciously and instinctively takes in the normal erect position when he wishes to "sniff the air." This throws the cervical vertebrae in normal relationship with the dorsal vertebrae, head slightly extended on the atlas, with the mandible approximately at a right angle to the table, and the air passages from nose to glottis as free as possible. After preliminary cocaineization of the selected nostril, nasopharynx and larynx,

the tube is often tolerated without coughing, even under light anesthesia. The cocaineization not only anesthetizes the mucous membrane but, through its shrinking effect on nasal tissues, increases the space available for the passage of the tube and decreases the possibility of epistaxis.

Although blind intubation can be performed under topical or any plane of general anesthesia, there is a decided difference of opinion as to the influence of the plane of anesthesia on the ease of intubation. Magill believes that it is easiest before the onset of relaxation as the neck muscles draw the epiglottis forward, out of the line of the glottic opening. Some anesthetists believe that relaxation facilitates nasal intubation. Lundy⁷ has found that nasal intubation can often be accomplished if it is synchronized with the first respiratory movements after respiratory obstruction has been produced by depressing the chin. During this period of respiratory obstruction the carbon dioxide content of the blood is elevated and the pharyngeal muscles are tensed to carry out the much needed inspiratory phase of respiration. When the chin is elevated and the obstruction relieved, the tube is guided into the trachea by the action of the pharyngeal muscles during inspiration.

With the head in the described position, the proper sized endotracheal tube is lubricated and passed through the vestibule of the nose so that it passes along the floor of the nostril close to the septum. While the tube is held in the right hand, the left hand is placed so that the fifth finger touches the larynx, the fourth finger holds up the chin, the third finger pushes the lips together, the index finger compresses the open nostril and the thumb rests on the tip of the mastoid process. With the left hand so placed, the head is firmly held and the respirations must of necessity be carried on through the intubed nostril.

As the endotracheal tube is progressively introduced into the nose, if the anesthetist listens near the open end, the respiratory sounds become louder and louder as the glottic opening is approached. Much of the success of blind nasotracheal intubation depends on the use of these respiratory sounds in guiding the tube into the larynx, and normal respiratory exchange is necessary. If the tube fails to enter the trachea, it usually enters the esophagus or goes laterally into the piriform sinus; in either case the respiratory sounds disappear and no air passes through the tube. Withdrawal of the tube until respiratory sounds are again heard, then rotation from side to side, as indicated, to return the tip of the tube to the midline may be tried. Occasionally, gentle manipulation of the larynx with the little finger of the left hand may be required in addition. Use of the opposite nostril occasionally brings success as, at times, does elevation of the head on the trunk.

If the above-mentioned maneuvers fail after several attempts to place

the endotracheal tube in the trachea, the larynx should be exposed with the laryngoscope, the tube grasped with suitable forceps and directed into the glottic opening.

Frequently, when the nasotracheal method is to be employed, intubation is carried out after the larynx has been exposed with the laryngoscope and the larynx cocaineized, no attempt being made to introduce the tube blindly.

Oral Endotracheal Method.—There are three variations of the oral endotracheal method of intubation. The first in which the endotracheal tube is inserted straight through the laryngoscope after the larynx has been exposed is called the direct method and will be described in detail later.

Indirect Method.—The second in which the endotracheal tube is inserted outside or around the laryngoscope without the larynx being under direct vision is called the indirect method. Occasionally this method is valuable when full view of the larynx is obstructed by an intra-oral tumor or by an extra-oral mass, such as a large adenomatous goiter displacing the larynx and trachea from their normal confines. When the epiglottis is located, it can be elevated slightly or a curved Magill tube may be directed under the epiglottis and into the larynx.

Blind Intubation by Touch.—The third variation, blind intubation by touch, has been developed and used by only a few anesthetists. This technic demands deep anesthesia with complete relaxation, the possession of fairly long fingers by the anesthetist is extremely helpful. Although this method is much more useful in children than in adults, every anesthetist should be acquainted with it as a life may be saved from the timely introduction of an endotracheal tube during an emergency when a laryngoscope is not available.

The anesthetist stands facing the patient and on the right side (if he is right handed). The mouth is opened wide with the mouth gag and the tongue is pulled well forward. The left index and middle fingers are passed into the mouth along the dorsum of the tongue and the epiglottis is palpated. It is elevated and the arytenoid cartilage is located with the middle finger. Then the tube is passed into the mouth along the groove formed by the index and middle finger. A Magill or woven-silk catheter bent in almost a quarter circle functions best for this type of intubation.

Direct Method.—As mentioned previously, in the direct method of intubation the larynx is exposed by means of a laryngoscope and the endotracheal tube inserted through the speculum into the larynx under direct vision. Although this procedure may be done under topical anesthesia, it is more often performed after the patient has been anesthetized with some general anesthetic agent. Laryngoscopy should not be attempted until anesthesia has been deepened to the point that the masse-

ter muscles are relaxed and the pharyngeal and laryngeal reflexes suppressed.

POSITION OF THE PATIENT'S HEAD

Jackson⁶ has described two positions of the patient's head on the table, either of which tends in certain respects to facilitate the laryngeal exposure. The position of choice is the one which best suits the anesthetist's needs and this will, in a measure, be influenced by the method followed in introducing the laryngoscope. These positions of the head are the "classical" described in 1913 by Jackson and his newer or amended positions (Fig. 379). In the classical position the patient's head must be in full extension, with the vertex firmly pushed down toward the feet so that the mouth opens and the tongue drops down. In this position the neck muscles are on the stretch and the distance from the teeth to the glottis is increased. In the amended position, the head is raised 10 cm.

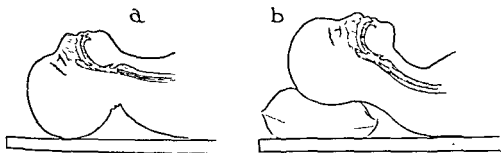


Fig. 379—Position of head for laryngoscopy *a*, "Classical," *b*, amended

above the level of the table and slightly extended so that the neck muscles are relaxed and the distance from the teeth to the glottis is decreased. When the amended position is used, the mouth does not fall open and the blade of the laryngoscope or the index finger of the right hand is inserted into the mouth to push the tongue forward, making room for the passage of the laryngoscope. The other manipulations of the laryngoscope are the same as when the classical position is used.

INTRODUCTION OF THE LARYNGOSCOPE

For the mere economy of motion, it is advisable for the beginner to learn to introduce the laryngoscope with his left hand and pass the endotracheal tube with his right hand. More important, however, is that the laryngoscopy be done in an efficient, rapid, but atraumatic manner.

The laryngoscope may be introduced in the midline or from the side of the mouth. The use of the median line makes recognition of structures easy but involves passing the laryngoscope over the incisor teeth which

are more easily damaged than the molars. Furthermore, the exposure of the larynx may be quite difficult or impossible when the central incisors protrude or the mandible recedes markedly. When the more desirable lateral route is used, the laryngoscope enters the mouth at the right

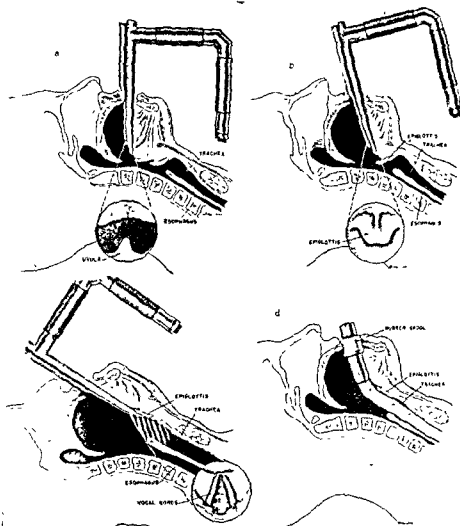


Fig 380 — Exposure of larynx for endotracheal intubation *a*, Laryngoscope introduced into mouth *b*, Exposure of the epiglottis *c*, Elevation of the epiglottis with exposure of larynx *d*, Flexible metal endotracheal tube in place

corner and passes into the pharynx over the molar teeth, while the tongue is displaced to the opposite side and anteriorly. The accompanying illustrations show the laryngoscope being introduced into the mouth by the median route (Fig. 380, *a*). For the sake of clarity the position of

the anesthetist's hands and the lead plate used to protect the teeth are not shown.

If the classical position is to be employed, the occiput is pushed downward toward the feet in order to throw the chin up and the mouth open. A lead plate is placed over the incisor teeth with the right hand while the upper and lower lips are held apart. The laryngoscope, held in the left hand, is passed into the mouth along the dorsum of the tongue. The upper lip is retracted so that it cannot be caught between the speculum and the upper teeth and the fingers of the right hand are used to steady the lead plate while the thumb is placed on the base of the blade and the speculum is gently advanced. With the laryngoscope thus placed in the mouth it is advanced until the base of the tongue and the uvula come into view (Fig. 380, *a*). With the speculum steadied by the thumb and index finger of the right hand, the left hand is shifted to the horizontal bar of the laryngoscope. As the base of the tongue is elevated, the epiglottis comes into view (Fig. 380, *b*). In exposing the epiglottis it is important that the laryngoscope be lifted so that the lower jaw and tongue are displaced forward, increasing the distance between the posterior pharyngeal wall and the base of the tongue. When the speculum of the laryngoscope is incorrectly used as a lever and the teeth are used as a fulcrum in an attempt to accomplish this exposure of the epiglottis, the teeth are likely to be broken. The tip of the speculum is depressed to pass the epiglottis and it is advanced until it is about 1 cm. beyond the epiglottis. With the speculum so placed, the lifting motion is again applied to the laryngoscope, and the larynx should be brought into view (Fig. 380, *c*).

If after this maneuver the larynx cannot be seen, the speculum probably has been advanced too far and has entered the esophagus. The larynx may be exposed from this position, however, by carefully withdrawing the speculum and allowing the larynx to drop down, exposing in order the corniculate, cuneiform and arytenoid cartilages in the glottic opening (Fig. 381). Occasionally the epiglottis may be extremely flexible and when its elevation is attempted, it will fall back on itself and partially or completely obstruct the view of the laryngeal opening. In some patients just the dorsal third or half of the larynx can be brought into view without the use of considerable force on the laryngoscope. If in such a case an assistant will make downward pressure from the outside on the larynx it will help to expose the entire laryngeal opening.

Much difficulty can be prevented in doing a laryngoscopy if the anesthetist will always remember that the epiglottis serves as a fixed landmark, just as the carina does in bronchoscopy and, therefore, the epiglottis should always be exposed and used as a means of orientation.

Whenever the anatomy seen through the laryngoscope is unfamiliar, one should again find the epiglottis and re-orient himself.

ANESTHETIZATION OF THE TRACHEA

Laryngeal spasm with its associated spasm of all the muscles of respiration and the ensuing apnea that inevitably occurs can be prevented in

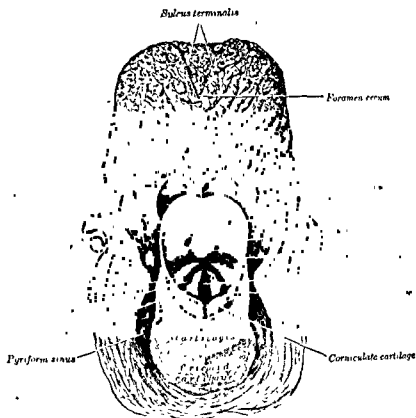


Fig 381 —The entrance to the larynx, viewed from behind. (From Gray's Anatomy, ed 25, Lea & Febiger)

most cases if the pharynx, larynx and trachea are sprayed with one of the topical anesthetic agents. This may be done before induction of anesthesia, as described in the paragraph on intubation under topical anesthesia, or it may be carried out after the larynx has been exposed. The tip of the long, straight atomizer, either Rowbotham or DeVilbiss as shown in Figure 376, is passed through the laryngoscope between the abducted cords, and the trachea sprayed. The tip of the atomizer is then withdrawn and the larynx and posterior pharynx are sprayed. When

done in this order the trachea is sure to be anesthetized, but if the larynx is sprayed first, the cords are likely to close when hit by the spray of local anesthetic agent and, consequently, none of it will reach the trachea. When the patient is under general anesthesia, I believe it is a waste of time to spray an anesthetic agent on the cords and trachea and follow this immediately with the introduction of the endotracheal tube. Insufficient time is thus allowed to elapse and no real anesthetization is gained by the topical application. A much better plan is to remove the laryngoscope after the cocaineization, continue the administration of the general anesthetic for another three to five minutes, allowing the topical agent to produce its effect, and then, on re-exposing the larynx, introduce the tube and, in this fashion, gain the benefit of the depressed reflex irritability of the larynx and trachea.

INTRODUCTION OF THE ENDOTRACHEAL TUBE

When a clear view of the trachea has been obtained and its anesthetization completed, an endotracheal tube previously lubricated is slipped through the glottis into the trachea (Fig. 380, *d*). If there is movement of the cords, the time when they are in greatest abduction should be chosen for intubation. The catheter should be passed with one rapid, gentle motion, touching the cords as little as possible. If the tube is passed at the side of the laryngoscope, the view of the cords remains unobstructed and the tube approaches them from behind and to the right, but when the tube is passed directly down the speculum of the laryngoscope, and the cords are observed through the stilet, the view of the cords is lost when the tip of the tube passes the light of the laryngoscope. Trauma to the cords should be avoided as a break in the mucous membrane covering them is likely to be followed by infection which leads to granulomatous polyps and changes in voice, and subsequently surgical removal of these growths may be required to restore the voice to normal.

WITHDRAWAL OF THE LARYNGOSCOPE

After the tube has been passed into the trachea it is held in place with the right hand while the left hand gently withdraws the laryngoscope. The lead plate is then removed and the rubber spool on the hilt of the tube is adjusted between the teeth to prevent the patient from biting the tube (Fig. 380, *d*). It is well to listen near the end of the tube where the strong expiratory phase of respiration, with its accompanying blast of air, can be heard. This gives real assurance that the tube is in the trachea and not in the esophagus.

SPECIAL CONSIDERATIONS

be placed over it just as is done when an oral or nasal airway is employed. Anesthesia may be administered without a face mask by using the Guedel-Waters inflatable cuff on the endotracheal tube and connecting the tube to the anesthetic supply by an adapter. Adhesive tape is used to hold the tube in place to prevent the spool from slipping out from between the teeth. When an operation is to be performed on the face, it is helpful to use the long Woodbridge tube with an endotracheal cuff and an adapter. This long tube may be brought out the corner of the mouth on the side opposite the operation, thus allowing the surgeon ample room. In the absence of an endotracheal tube with an inflatable cuff, packing of the oral

pharynx very firmly to secure an air-tight fit. This packing may cause pressure necrosis in the tonsillar area and a subsequent sore throat if the operation lasts more than two hours. Another disadvantage to the use of an oral pack is that aspiration of vomitus into the trachea is still possible, this is avoided, however, when an inflatable cuff is used.

PROLONGED USE OF ENDOTRACHEAL TUBES IN COMATOSE PATIENTS

After a rather large experience with the use of endotracheal tubes to insure an adequate airway in patients suffering from coma, we have more or less abandoned this procedure in favor of early tracheotomy. Our reasons for doing so are as follows: (1) tracheotomy is more physiologic—the presence of an endotracheal tube acts as an irritant causing a productive tracheobronchitis. (2) Tracheotomy insures a better avenue for the removal of excess secretions by the nursing staff. (3) Alterations have been noted in the tracheal mucous membrane and granulomatous polyps have been seen on the vocal cords following the prolonged use of endotracheal tubes. (4) There is always the possibility of an endotracheal tube becoming obstructed or inadvertently removed and the patient dying of asphyxia; this is much less likely to happen after a tracheotomy has been performed.

MISCELLANEOUS

Before insertion of an endotracheal tube that has an inflatable cuff on it, the cuff should be inflated and inspected for leaks. Over-inflation of the cuff after placing it in the trachea may be responsible for trauma to the tracheal mucosa. Gillespie gives a practical test to ascertain the minimal necessary pressure. A dry syringe fitted with a blunt, wide gauge

needle is inserted in the inflating tube and the air is gently injected into the cuff while pressure is exerted on the breathing bag. The inflation of the cuff is discontinued as soon as it reaches the point where it just prevents the leakage of gas which has been taking place until that time owing to the manual pressure on the breathing bag. Some of the inflatable cuffs are now being manufactured with small pilot cuffs near the distal end of the inflating tube. A relatively good idea of the amount of tension on the cuff in the trachea may be gained by observing the pilot cuff as the air is injected.

When mucus collects in an endotracheal tube during an operation, it may be removed by passing a sterile number 14 or 16 French ureteral catheter into the tube, applying suction and removing the debris (Fig

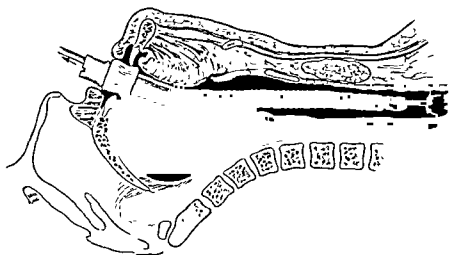


Fig 382—Catheter passed through endotracheal tube for the removal of mucus from the trachea.

382). The same procedure is of extreme importance in removing the pus that accumulates in an endotracheal tube during operations on patients suffering from suppurative diseases of the lungs. We have found a 16 gauge Levin tube, with its distal end prepared so that there is a single end opening, to be of great assistance in removal of secretions from the right and left main stem bronchi during thoracic operations; these secretions cannot be reached with the ordinary urethral catheter. Small sized polyethylene plastic tubing has proved to be invaluable for the aspiration of mucus from the small bore endotracheal tubes used in pediatric anesthesia. In severe bronchiectasis or lung abscess it is often advisable to do a preoperative and postoperative bronchoscopy in order to remove the accumulated secretions so that the patient will not drown in them either during induction or during the postoperative recovery.

Although 10 per cent cocaine is advocated and used as a routine topical

anesthetic agent for endotracheal intubation, undesirable cocaine reactions are almost never seen. This may be explained by the fact that all conscious patients are advised and urged to expectorate any excess solution that may pool in the posterior pharynx rather than to swallow it, for it is thought that it is rapidly absorbed from the stomach; in addition, the cocaine causes vasoconstriction of the mucous membrane and this is believed to hinder its absorption. In addition to these above-mentioned features which militate against the occurrence of cocaine reactions,

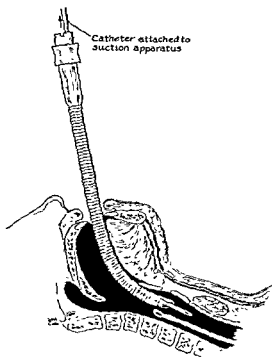


Fig 383.—Aspiration through endotracheal tube during its removal from the trachea

most of the patients receive some type of general anesthesia and this, of course, depresses the sensitivity of the cerebral cortex to stimulation.

At the end of the operation certain complications are likely to occur when the endotracheal tube is removed. Blood, pus or mucus may be aspirated into the trachea unless the nasopharynx is cleared of foreign material by preliminary aspiration and a catheter subsequently introduced into the endotracheal tube so that it extends beyond the tip and suction applied continuously as the tube is withdrawn so as to remove any material that may be trapped between the tube and the tracheal wall (Fig 383). The pharyngeal toilet and removal of the endotracheal catheter will often precipitate a spasm of the glottis if the patient is lightly anesthetized. Therefore, I believe that the anesthesia should not

be too light at the time of extubation. A mouth gag placed between the teeth or a metal oropharyngeal tube will prevent the patient from biting the tube and also lessen the possibility of injury to the patient's throat during extubation. The insertion of the pharyngeal airway before the tube is removed will generally prevent the common type of obstruction seen in the anesthetized patient when the tongue is allowed to fall back against the posterior pharyngeal wall.

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THE SURGICAL CLINICS of NORTH AMERICA

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SYMPOSIUM ON TRAUMATIC SURGERY

INJURIES TO THE PERIPHERAL NERVES AND THEIR TREATMENT

WINCHELL MCK. CRAIG AND COLLIN S. MACCARTY

Great advances in the treatment of injuries of the peripheral nerves have come from World Wars I and II. These advances have come not through the efforts in any single field of medicine or surgery, but from the co-operative efforts of biologists, physiologists, neurologists, orthopedists, neurologic surgeons, plastic surgeons and pathologists. The approximation of the severed ends of a peripheral nerve is of paramount importance, but coincidental treatment of other component parts of the extremities should not be overlooked if the maximal recovery of the extremity is to be achieved. This concept, developed in the recent war, has been carried into civilian practice as one of the truly great advances in the field of surgery and medicine. A partially or completely denervated extremity is incapable of performing normal activities. Muscular inactivity, dysfunction and vascular and trophic changes contribute to the discomfort and disability. It is the purpose of neurologic surgery to contribute to the restoration of activity and function of the extremity.

Seddon on the basis of his experiences in 460 cases reported that clinical manifestations of damage to peripheral nerves may be considered under two headings: (1) those due to loss of function and (2) those due to perversion of function. In the first, the injury to the efferent system, which consists of loss of continuity, results in paralysis of muscles, sudomotor paralysis and pilomotor and vasomotor paralysis (fig. 384). In the afferent system tactile sensibility, sensibility to pain, thermosensibility, joint and postural sensibility and deep sensibility are lost. In the group in which clinical manifestations show perversion of function, the efferent impulses are manifest by muscle twitching and spasm, abnormal sweating and vasomotor disturbances. The afferent impulses are perverted and show paresthesias, apparently spontaneous

pain, pain outside the range of normal experience and abnormal responses to heat and cold.

Seddon suggested also that three types of lesions of peripheral nerves may produce the two types of clinical response. The first and most obvious one is complete anatomic division of the nerves. The second is a lesion in continuity in which more or less of the supporting structure of the nerve is preserved but disturbances of the nerve fibers are such that true wallerian degeneration occurs peripherally. The third is a transient block consisting of a minimal lesion of the nerve which produces paralysis that is incomplete, more often than not and is accompanied by peripheral degeneration; recovery to this type is rapid and

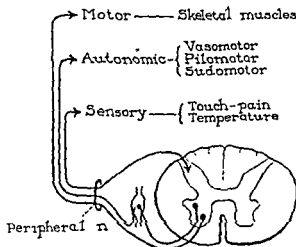


Fig. 384 —Outline of the principal components of a peripheral nerve showing the somatic motor component to skeletal muscles, the autonomic motor components to involuntary muscles and the sensory somatic component. The visceral sensory component which travels by way of the autonomic system to the posterior root is not shown (Craig in Walters-Lewis Practice of Surgery, published by W. F. Prior Company)

complete. It is apparent from the physiologic standpoint, as well as the clinical standpoint, that the motor and autonomic functions of most peripheral nerves are most important. There are, of course, certain instances in which the sensory components are far more important than the motor components and the loss of the sensory components are far more disabling than the loss of the motor components.

THE APPROACH, CONCOMITANT INJURIES AND TIME OF OPERATION

In the perfect situation the combined efforts of the various surgical specialties result in adequate treatment of injuries to extremities. The plastic surgeon emphasizes certain fundamentals involved in the res-

toration of skin, subcutaneous tissues and muscles. The vascular and orthopedic surgeons emphasize some of the fundamentals involved in the treatment of injuries of bones, joints, blood vessels and tendons. Learmonth and Wallace and Bunnell were among the first to call attention to the fact that overlying tissues should be restored before surgical treatment of some of the peripheral nerves is attempted. Webster, Shelden, and Pudenz referred to the work of Learmonth and Wallace, Bunnell and others and emphasized the need of a plastic surgical approach in exposure of the peripheral nerves. They decried the usual linear incision which transverses skin creases overlying joints because of the disfiguring and disabling scars which may result. They applied an S-shaped incision for exposure of nerves. Seletz in a comprehensive study of 1,567 lesions of peripheral nerves emphasized adequate exposure and stated that the approach to deep lying nerves should be through fascial planes, rather than by penetration of the muscle substance. He also stated that when a muscle must be penetrated, it should always be split in the direction of its fibers. When a muscle must be divided, it should be severed at its tendinous attachment or origin where it can be easily repaired. Shortening of long bones or resection of the clavicle should be avoided when possible. When scars produce traction because of improperly placed incisions over joints, it must be remembered that the skin and also the subcutaneous tissues and fascial layers are involved.

Elkin and Woodhall stated that vascular injuries and concomitant injuries in World War II surpassed that of any other war. They observed that with improved methods of control of shock and infection, a greater number of soldiers who had such injuries were saved for subsequent observation. Massive vascular injuries frequently obscure nerve injuries and conversely obvious nerve injuries frequently obscure less pronounced vascular injuries. These facts must be borne in mind because, as a general rule, all large blood vessels with a few exceptions are accompanied by peripheral nerves. The most critical condition obviously should be treated first. Aneurysms whether arterial or arterio-venous rarely need emergency treatment unless the aneurysm is progressing rapidly in size or has ruptured or unless heart failure is impending. Time ordinarily should be allowed for collateral circulation to develop. This frequently is improved by operations on the sympathetic nerves. Complete excision of an arterial aneurysm, for instance, together with repair of the nerve at a single operation is really the preferred method.

Spurling¹⁴ from his vast experiences in World War II emphasized that there were two types of sutures of nerves which may be carried out with regard to time of injury, namely, the primary suture and the

delayed suture. Woodhall and Lyons reviewed the result of early nerve suture in nineteen separate neurosurgical centers. They concluded that the percentage of failures is far greater when nerve suture is performed at the time of débridement than when it is deferred until after delayed closure of the wound. Available evidence suggested to them that primary suture was of dubious value at the time of wound revision. They felt that suture of nerves performed after delayed closure of the wound failed only infrequently and that these failures could be traced to two main causes, inept surgical technic and inadequate immobilization or no immobilization at all of the extremity after neurorrhaphy. They stated that it is impossible to predict in most cases the eventual outcome in a contused peripheral nerve visualized at débridement. As a result of some injuries neuromas in continuity may develop which may offer a more or less complete barrier to regeneration. Even the divided nerve may be inadequately sutured at the time of injury because of the unknown extent of neuroma which develops even with good anatomic repair. Therefore, three months after injury is an adequate time to evaluate the neuroma in continuity and the neuroma in the proximal stump of a severed nerve. At this time proper resection of the neuromas can be carried out and an adequate approximation of the viable stumps of peripheral nerves may be accomplished.

INJURIES TO THE BRACHIAL PLEXUS AND CONTIGUOUS NERVES

Chronologically the earliest type of peripheral nerve injury is a birth palsy due to avulsion of a portion or all of a brachial plexus or its trunks during parturition (fig. 385). Adults also may have a stretch injury due the effects of sharp blows on the shoulder or side of the head and sometimes to twisting or circular motion, which put the plexus under tremendous tension. War injuries to the brachial plexus are usually due to direct penetration trauma. Both stretch and penetration injuries are frequent in civilian practice.

Anatomy of Brachial Plexus.—Practically speaking, the brachial plexus extends from the spinal cord to the inferior border of the pectoralis major muscle (fig. 386). Usually the brachial plexus arises from the anterior roots of the fifth, sixth, seventh and eighth cervical and the first thoracic nerves. The outline (fig. 387) of the brachial plexus in its simplest form is as follows: The fifth and sixth anterior cervical roots fuse to form the upper trunk. The anterior seventh root comprises the middle trunk and the anterior eighth cervical and part of the anterior first thoracic roots form the lower trunk. These trunks are close to the foramina and emerge from under the scalenus anticus muscle or through the muscle essentially in the supraclavicular fossa. The secondary cords of the plexus pass under the clavicle and arise from these primary

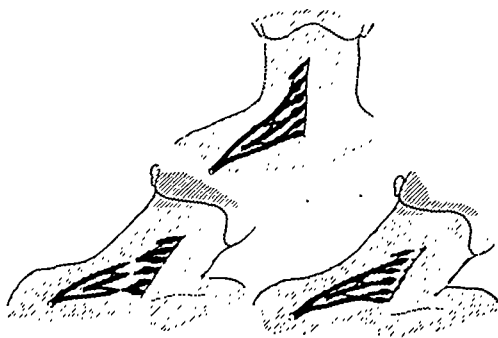


Fig. 385.—The mechanism of avulsion of the brachial plexus. (Craig and MacCarty in Walters-Lewis Practice of Surgery, published by W. F. Prior Company.)

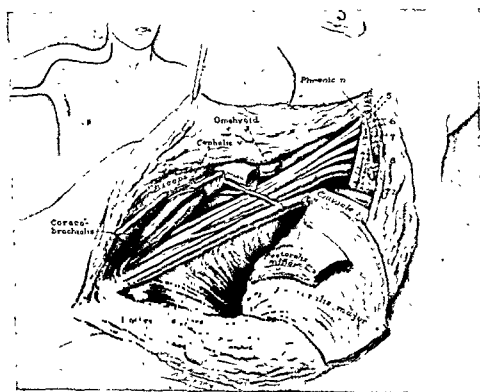


Fig. 386.—Surgical exposure of the brachial plexus. (Craig and MacCarty in Walters-Lewis Practice of Surgery, published by W. F. Prior Company.)

trunks. The posterior cord is formed by the posterior divisions of all the trunks. The medial cord arises from the anterior division of the lower trunk. The lateral cord arises from the anterior divisions of the upper and middle trunks. The cords terminate as the major nerves of the upper extremity. The posterior cord terminates as the axillary and radial nerves. The lateral cord terminates as the musculocutaneous nerve or nerves and lateral head of the median nerve. The medial cord terminates as the medial head of the median nerve, the ulnar nerve, medial antibrachial cutaneous nerve and the medial brachial cutaneous nerve. Other secondarily important nerves arise from the roots, trunks and cords of the plexus. The fifth cervical nerve sends a branch, the

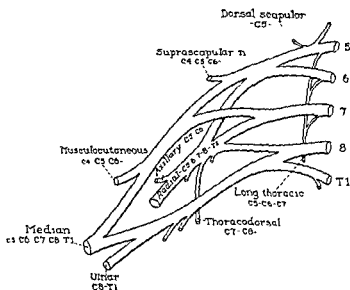


Fig 387 —The brachial plexus and its terminal nerves in outline (Craig and MacCarty in Walters-Lewis Practice of Surgery, published by W. F. Prior Company.)

dorsal scapular nerve, to the rhomboids. The fifth, sixth, and seventh cervical nerves form the long thoracic nerve which supplies the serratus anterior or magnus muscle. The suprascapular nerve arises from branches of the fifth and sixth cervical nerve and lies on top of the plexus until it passes over the scapula to innervate the supraspinatus and infraspinatus muscles. The anterior thoracic nerves to the pectoral muscles arise from the lateral and medial cords of the plexus. The subscapular nerves and thoracodorsal nerve come off of the posterior cord to supply the subscapularis muscle, latissimus dorsi and teres major muscles.

The brachial plexus has many anatomic anomalies. The origin of the

entire plexus may be one segment cephalad or caudad with the resultant prefixed or postfixed plexus. In either of these circumstances, however, the relative position of the elements of the plexus usually are unchanged.^{3, 4} Most anomalies involve the terminal portion of the plexus but occasionally the entire plexus may be anomalous. Plexuses in which components were united to form a single cord have been reported.¹³

Phylogenetically the median, ulnar and musculocutaneous nerves are closely related; presumably they arise by evolution from a single primary ventral nerve trunk. This is seen in lower animals, amphibians, reptiles and birds. The extensor nerve trunk of these lower animals has persisted in man as the radial nerve. Higher in the animal scale differentiation becomes more frequent. It is generally agreed that most anomalies in man are in reality a partial return to a more primitive structural arrangement.^{5, 8} Anomalies of blood vessels are frequently seen in association with anomalies of nerves. In our experience at the United States Naval Hospital, Bethesda, Maryland, most anomalies encountered in treatment of the war injuries there, involved the lateral and median cords and their terminal nerves. An excellent example of this was encountered by one of us (C. S. M.) in which an extra nerve was noted coming from the lateral cord. On electrical stimulation of this exposed nerve contractions were noted in the biceps muscle similar to those usually produced by stimulation of the musculocutaneous nerve and in addition contractures were observed in the long flexors of the forearm. This nerve, therefore, seemed to be a combined median and musculocutaneous nerve. However, an apparently normal median nerve was observed coming from the medial and lateral cords in true anatomic fashion and also there was a good musculocutaneous nerve coming from the lateral cord. In other words, this type of anomaly might make the diagnosis of an injury in this region difficult, because, if the median nerve had been entirely divided, the patient could still flex the fingers and wrists.

Neurologic Manifestations of Injuries to Brachial Plexus.—Without detailed neurologic description of the various types of injuries to the peripheral nerves and brachial plexus, it seems important to outline a few fundamental neurologic manifestations of these injuries which are indicative of the site of the injury. An injury to the proximal portion of the plexus, proximal to the dorsalis scapulae or long thoracic nerve, an injury in other words, which is at the foramen or is interspinal, results frequently in a wing scapula due to paralysis of the serratus anterior, rhomboid and levator scapulae muscles. If an injury is in the proximal portion of the plexus and involves the lower root to the plexus, Horner's syndrome frequently may be present. This is due to involvement of the first thoracic root and its intrinsic sympathetic nerve supply to the eye.

Injuries to the upper roots and upper trunk of the plexus, peripheral to the long thoracic and dorsalis scapulae nerves, preserve the function of the scapula and a wing scapula does not persist or exist. However, paralysis of the upper arm due to paralysis of the supraspinatus, infraspinatus and deltoid muscles, may result from injury to the supra-scapular and axillary nerves. This results in inability to elevate and abduct the arm.

Injuries of the seventh cervical root or middle trunk result in weakness of the extensor muscles of the arm and forearm as the radial nerve is chiefly supplied from this root.

Injuries to the lower trunk or its components, the eighth cervical and first thoracic nerves, result in paralysis involving the lower components of the plexus. This will include the hands or distal portions of the extremities which are supplied chiefly by the ulnar nerve. Horner's syndrome is present frequently because of paralysis of the sympathetic nerve fibers in the first thoracic nerve.

For practical purposes the neurologic manifestation of injuries to the proximal portion of the brachial plexus may be summarized as follows: In lesions involving the upper trunk the motor deficit largely results in inability of the shoulder girdle to function properly. This is manifest by inability to abduct the arm at the shoulder. Injuries to the middle trunk result in considerable radial incapacity. Injuries to the lower trunk disable the hand and forearm. The sensory deficit in these types of injuries may be readily appreciated by the accompanying diagram (fig. 388)

Defects in the cords are manifest by paralysis and sensory loss in the terminal nerves. From above downward then defects of the lateral cord result in paralysis of the part supplied by the musculocutaneous nerve and the lateral head of the median nerve with associated paralysis of the part supplied by the lateral anterior thoracic nerve. The lateral head of the median nerve in our experience supplies the pronator radii teres muscle and the flexor carpi radialis muscle in the realms of the median nerve supply. The musculocutaneous nerve supplies the flexors of the forearm on the arm in that it supplies essentially the biceps and coracobrachialis muscles. The lateral anterior thoracic nerves are a portion of the supply to the pectoralis muscles. The resultant paralysis from involvement of the lateral cord, therefore, is one of considerable importance. Because of the paralysis of the biceps and coracobrachialis muscles there is inability to flex the forearm on the arm and there is paralysis of the pronator teres and brachioradialis muscles and atrophy which is noticeable and characteristic. The weakness of the pectoralis major muscle is minimal because of the dual supply from the anterior thoracic nerves. Sensory loss in this type of paralysis corresponds to the musculocutaneous distribution in the forearm.

The medial cord of the plexus supplies the major portion of the median nerve and all of the ulnar nerve along with the medial antibrachial cutaneous and medial brachial cutaneous sensory nerves. As a result of paralysis of the medial cord, there is complete paralysis of the distribution of the ulnar nerve and of the median nerve except for the pronator teres and flexor carpi radialis muscles, the function of which is preserved inasmuch as their innervation is from the lateral head of the median from the lateral cord. There is also a most disabling median sensory loss (fig. 389). The pectoralis muscles are slightly weak because

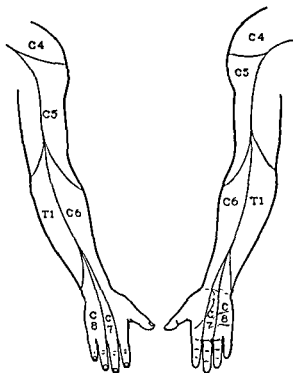


Fig. 388.—Sensory distribution of the roots of the brachial plexus. (Craig and MacCarty in *Walters-Lewis Practice of Surgery*, published by W. F. Prior Company.)

of the medial anterior thoracic nerves which come from the medial cord. An injury to the posterior cord of the brachial plexus results in paralysis of the axillary and radial nerves; the two great extensor nerves of the body. One, the axillary, abducts the arm at the shoulder joint, the other, the radial, supplies the extensors of the forearm on the arm, the hand on the forearm and the fingers on the hand. The sensory loss of the posterior cord is the same as the sensory loss to the axillary and radial nerves (fig. 390).

Treatment of Injuries of the Brachial Plexus.—The treatment of injuries to the brachial plexus has always been a confused issue to the general practitioner and surgeon who is not well acquainted with this type of injury. In treating traction injuries to the plexus which occur

at birth a definite program should be followed. The usual type of injury involves the upper two roots. Occasionally a lower type of plexus injury will occur. Immediately after injury there is a primary traumatic neuritis with considerable tenderness and pain in the region of the brachial plexus. The arm is flaccid. This period of neuritis usually lasts for the first two or three weeks of life. At this point it is imperative to stop all motion in the extremity. The best position is abduction of the

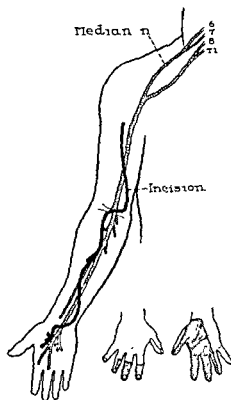


Fig. 389 — Incision for exposure of the median nerve and sensory pattern of the median nerve. (Craig in *Walters-Lewis Practice of Surgery* published by W. F. Prior Company.)

arm at the shoulder to 90 degrees, flexion of the elbow to 90 degrees, external rotation of the humerus until the forearm lies in the coronal planes, supination of the forearm until the palm of the hand faces the skull and extension of the hand, wrist and fingers in a straight line with the forearm. This position is best maintained by a brace made to fit the child. When the period of neuritis is past, the extremity should be moved from its fixed position twice a day, given gentle massage and moved passively. When motion appears in the paralyzed extremity, muscle training should begin under the expert care of the physical therapist. Operative treatment of this type of injury may be delayed

until maximal recovery seems to have been reached. This may be as long as a year after the child's birth. It is indeed a rare occasion when these injuries require anastomosis of the nerve. They are for the most part stretch injuries. The most that can be accomplished by operation is neurolysis of the stretched roots.

In treating traction or stretch injuries to the brachial plexuses of adults, on the other hand, we are more inclined to intervene surgically

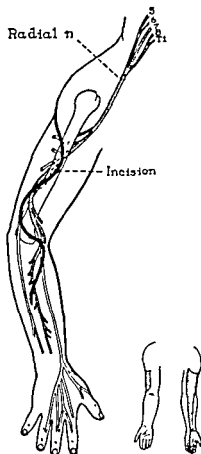


Fig. 390.--Incision for exposure of radial nerve and sensory pattern of the posterior cord. (Craig in Walters-Lewis Practice of Surgery, published by W. F. Prior Company.)

sooner because the risk of operation is less and because a maximal amount of information can be gained by exploring the plexus of adults.

For other types of injuries to the brachial plexus, surgical procedures are indicated only when penetrating wounds of the thorax producing massive hemorrhage, pneumothorax or other conditions requiring life-saving measures have been cared for; when there is rapid progressive recovery after the initial shocklike state which may last for several days; when vascular insufficiency has been overcome by sympathectomy, repair of aneurysms, or other procedures; when infected wounds such as

those in cases of osteomyelitis and fistulous tracts have been cleaned up; when grafts have been applied to denuded regions and other plastic procedures have been carried out; when it is certain that permanent contractures or immobility of the joint will not result when an extremity is immobilized for anastomosis of nerves and when causalgia, if present, has been satisfactorily treated by sympathectomy. When all these conditions have been cared for, the plexus may be explored.

Injuries to Radial Nerve.—The radial nerve seems to be injured most frequently of all the peripheral nerves. Its fibers arise from the fifth, sixth, seventh, and eighth cervical nerve roots as well as the first thoracic nerve. It is a more primitive nerve analogous to the dorsal nerve of lower animals. It supplies the extensors of the forearm, hand and fingers in general. The sensory branches of the radial nerve supply the radial portion of the dorsum of the hands and fingers except the little finger, the ulnar side of the ring finger and a narrow band along the dorsum of the forearm. Injuries to this nerve may occur at almost any location, but occur most commonly along the shaft of the humerus in association with fractures of the humerus. Occasionally injuries occur at the upper end of the humerus, at the lower end of the plexus in the axilla due to fractures and dislocations at this site. A rather peculiar injury at this location results from pressure from crutches or sleeping with the head on the arm or pressure during unconsciousness. The so-called Saturday-night paralysis results from sleeping in this manner on a park bench. When the nerve is involved near its origin, all the muscles supplied by the nerve are paralyzed. This includes the triceps muscle as well as the extensors of the wrist and hand. After fracture of the humerus a nerve injury may be recognized early because of wristdrop. If wristdrop comes on late after a fracture of the humerus, the nerve usually has been injured by callus formation at the site of fracture. In this type of injury the innervation to the triceps muscle is of course spared. Regardless of the cause of the nerve injury in this location whether it is from immediate trauma due to the fracture or whether it is secondary to callus formation, the nerve should be explored and if it is severed, an anastomosis should be done. If the nerve is not severed but injured secondarily to pressure from the callus, the callus should be removed and neurolysis performed.

Another characteristic injury of the radial nerve which was seen to a great extent during the recent war occurs in the forearm. Mayer and Mayfield reported on a series of 58 patients who had this type of injury and were treated surgically for the lesion. This is an injury to the posterior interosseous nerve or the deep branch of the radial nerve in the forearm as it passes around the head of the radius. This injury produces a characteristic deformity due to paralysis of the extensors of the

proximal phalanges of the fingers but with preservation of extension of the wrist. The injury is below the level of the branches to the extensors to the wrist. Extension of the distal phalanges is preserved since this movement is performed by the interossei and lumbricales muscles which are supplied by the median and ulnar nerves. There is also paralysis of the extensors of the thumb and abductor longus of the thumb. Great care is needed in the exploration of this nerve between the brachioradialis muscles and extensor carpi radialis muscles so that the preserved motor nerve supply to the extensors of the wrist, the brachioradialis and extensor carpus longus muscles, are not injured. Anastomosis of the radial nerve is usually a relatively simple procedure and in general the results are good.

Injuries to Median Nerve.—The median nerve is derived from the sixth, seventh and eighth cervical and first thoracic nerves. In general it supplies all the anterior group of muscles in the forearm except the flexor carpi ulnaris and an indefinite inner portion of the flexor digitorum profundus which may vary with individuals. In the hand it supplies the opponens pollicis, flexor pollicis brevis, abductor pollicis brevis and the lateral two lumbricales. Lesions of the median nerve effect opposition of the thumb and little finger, flexion of the index finger and sometimes of the middle finger and generally abduction of the thumb. The great importance of this nerve is readily seen because in addition to the important muscles that it supplies it also carries the critical sensory nerves in the hand, it supplies most of the palm and the palmar surface of the thumb, first, second fingers and the lateral half of the fourth finger (fig. 389).

Injuries to the median nerve frequently occur at or about the wrist. The long flexors to the wrist, hand and fingers are spared. Tardy median paralysis or median thenar neuritis is a delayed paralysis due to injury of the median nerve at the wrist from the pressure of a hypertrophied transverse carpal ligament or from compression of the nerve in the immediate vicinity secondary to fracture about the wrist. This type of injury of course is treated by release of the pressure due to the hypertrophied ligament or callus.

The median nerve also is particularly susceptible to injury along the medial aspect of the upper arm along with injuries to the ulnar nerve. Injury to the median nerve at this site may result in paralysis of those muscles supplied by the nerve in the forearm with weakness and paralysis of flexion of the wrist and fingers in addition to paralysis of the intrinsic muscles of the hand and the sensory loss already mentioned. Because of the overlapping innervation of the flexor digitorum profundus muscle with the ulnar nerve complete median nerve paralysis in the arm may be present and the patient may still be able to flex all of

the fingers at their terminal phalanx except the index finger which seems to be exclusively innervated by the median nerve. From a diagnostic standpoint this is important. One other fact about the median nerve should be mentioned, and that is, that injuries to this nerve are frequently associated with causalgia which is dramatically relieved by sympathectomy.

Injuries to Ulnar Nerve.—The ulnar nerve derives its fibers from the eighth cervical and first thoracic nerves. In the forearm as mentioned previously the nerve supplies the flexor carpi ulnaris muscle and the medial aspect of the flexor digitorum profundus muscle. The ulnar nerve in the hand supplies all the intrinsic muscles that are not supplied by the median nerve. This includes the hyperthenar muscles, the adductor pollicis brevis, the abductor digiti quinti, the flexor digiti brevis and the two medially placed lumbricales muscles as well as all the interossei. Therefore, a lesion affecting the ulnar nerve results in tremendous weakness of the intrinsic muscles of the hands but the ability to abduct the thumb is spared although there is characteristic deformity which once seen is never forgotten. The terminal phalanges of the last two fingers cannot be flexed properly because of the paralysis of the outer portion of the flexor digitorum profundus muscle. There is wide separation of the thumb and index finger because of paralysis of the adductor pollicis muscles. Abduction of the little finger is impossible and marked atrophy is particularly apparent in the interossei and lumbricales muscles with resultant inability to abduct and adduct the fingers. The terminal phalanges of the last two fingers cannot be extended due to the paralysis of the lumbricales muscles. This deformity is called "main en griffe." The area of anesthesia associated with an ulnar nerve paralysis is confined to the fifth finger and the ulnar half of the fourth finger (fig. 391). If the ulnar nerve is injured below the elbow the flexor carpi ulnaris muscle and flexor digitorum profundus are spared. The ulnar nerve is frequently involved in injuries about the elbow. Many of these result in immediate paralysis and in others a tardy ulnar paralysis may come on many years after an injury to the elbow. This injury produces secondary changes in the internal condyle with the result that the ulnar nerve is exposed to constant trauma in the ulnar groove. This so-called tardy ulnar paralysis is easily treated by neurolysis and transplantation of the nerve underneath the flexor tendons on the anterior aspect of the forearm.

Injuries to Other Peripheral Nerves of Upper Extremity.—Of less importance are injuries to other peripheral nerves derived from the brachial plexus. Among these are the long thoracic nerve, dorsal scapular nerve or nerve to the rhomboids, and the subscapular group of nerves. Included in this group of course should be the musculocutaneous

nerve which supplies both heads of the biceps, the coracobrachialis and part of the brachialis muscles. Injury to the dorsal scapular nerve or nerve to the rhomboids results in winging of the scapula. Injury to the subscapular group of nerves produces little impairment and is usually associated with injuries to the posterior cord of the brachial plexus. Injury to the musculocutaneous nerve results in paralysis of the biceps

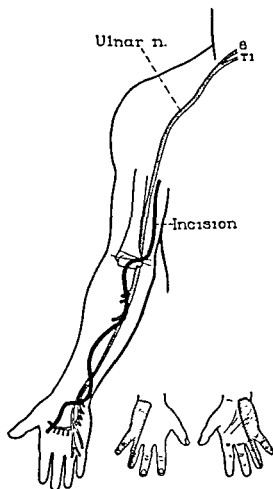


Fig. 391.—Incision for exposure of ulnar nerve and sensory pattern of the ulnar nerve. (Craig in Walters-Lewis Practice of Surgery, published by W. F. Prior Company.)

and coracobrachialis muscles. However, ability to flex the forearm on the arm frequently remains because the brachialis muscle has a dual nerve supply in most persons. The secondary supply comes from the radial nerve.

INJURIES TO LUMBOSACRAL PLEXUS AND SCIATIC NERVE

Wounds of the lower part of the abdomen and pelvis occasionally result in simultaneous injury to the lumbosacral plexus. The majority of

lesions, however, involve the sciatic and femoral nerves peripheral to the lumbosacral plexus. The sciatic nerve is derived from the anterior primary divisions of fifth lumbar, first, second and third sacral nerves and part of that from the fourth lumbar nerve. The sciatic nerve supplies the biceps femoris, semitendinosus, semimembranosus, all the flexors of the leg and the adductor magnus muscles. It divides into two large branches in the lower portion of the thigh; namely, the tibial and peroneal nerves. The sciatic nerve which usually is considered to be one trunk actually consists of two distinct divisions in a common sheath.

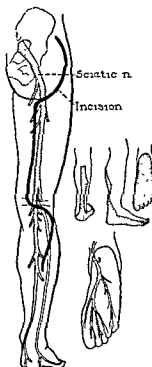


Fig 392 —Incision for exposure of the sciatic nerve and its terminal branches and sensory pattern of the tibial nerve. (Craig in Walters-Lewis Practice of Surgery, published by W F Prior Company.)

These divisions are the tibial and common peroneal nerves. A stretch injury of the sciatic nerve frequently injures only the peroneal division because of its peculiar anatomic position. Both divisions are fairly fixed at the lumbosacral plexus but the peroneal division is likewise fixed at the head of the fibula where it descends into the lower leg. The tibial division is not fixed at the knee joint; therefore a stretching injury or one caused by an explosive force near the sciatic nerve is likely to damage the peroneal division and frequently spares the tibial division. The tibial nerve supplies the gastrocnemius, plantaris soleus and

popliteus muscles. When this nerve is paralyzed, the patient is unable to stand on his toes. Generally speaking the tibial nerve supplies the intrinsic flexor muscles of the foot. The cutaneous branch of the tibial nerve supplies the lateral and posterior portions of the lower third of the leg, skin of the heel, and the medial side and the sole of the foot (fig. 392). Injury to this cutaneous branch is of extreme importance and results in considerable disability due to the anesthesia of the sole of the foot.

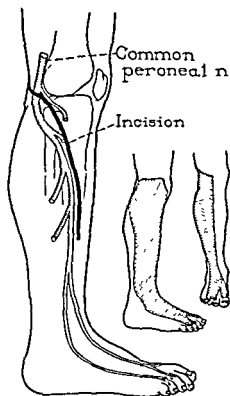


Fig. 393.—Incision for exposure of the peroneal nerve at the fibula and sensory pattern of common peroneal nerve. (Craig in Walters-Lewis Practice of Surgery, published by W. F. Prior Company.)

The common peroneal nerve descends from the popliteal space and crosses the upper part of the fibula. Its site makes it extremely vulnerable to wounds and fractures of the fibula as well as the stretch injuries. This nerve supplies the skin of the anterior and lateral surface of the leg and dorsum of the foot (fig. 393). As the nerve passes beneath the peroneal longus muscle it divides into the deep and superficial peroneal nerves. The deep nerve supplies the tibialis anterior, extensor hallucis longus, extensor digitorum longus and brevis, and the peroneus tertius muscle. These are all extensors of the foot and toes. The superficial branch supplies the peroneaeus longus and brevis muscles. For practical purposes the severe injury of the peroneal nerve results in

the classical drop foot type of deformity. The sensory loss as a result of injury to the peroneal nerve is not particularly disabling (fig. 303).

SURGICAL PROCEDURES AND CONSIDERATIONS

End-to-end suture of severed peripheral nerves has proved to be the most efficacious method of treatment. Extensive dissection of the nerve trunk makes it possible to overcome a gap of as much as 3 to 4 inches (7.6 to 10.2 cm). In this type of dissection great care must be taken to preserve the blood supply to the nerve as much as possible. The longitudinal blood supply is probably the most important. After the neuroma has been removed, the central stump is cut back until normal-appearing fasciculi are seen and brisk bleeding occurs. This bleeding may be controlled by the application of strips of muscle, fibrin foam or gel foam with thrombin over the ends of the nerve. The end-to-end anastomosis must be accomplished without tension. This frequently necessitates, in addition to the rather extensive dissection of the nerve, flexion of an adjacent joint. Flexion need not be maintained longer than four to six weeks and subsequent extension is allowed to occur through guarded physical therapy. Pudenz proved experimentally that tantalum wire, steel wire, nylon, human hair and black silk are among the suture materials which cause the least tissue reaction. During the recent war the line of suture was wrapped in tantalum foil to prevent adhesions and distortion of the line of suture. In the presence of infection, it was frequently necessary to remove these tantalum cuffs, and Spurling¹⁵ reported that the foil was frequently fragmented. We think that the tantalum cuff does protect the line of suture and possibly is beneficial in a clean wound. If there is any question, however, as to the cleanliness of the wound, this type of protective mechanism is best not used.

Young and Medawar first suggested the use of a plasma clot in repair of peripheral nerves. This procedure was later perfected by Tarlov and his associates^{16, 17} and was used in a number of neurosurgical centers during the recent war. We have had no experience with this procedure.

Because of the nature of most injuries, there is of necessity frequent, though minimal, tension on suture lines. With accurate approximation of the neurilemma, with accurate approximation of fasciculi which can be accomplished in most nerves by delicate suturing, it is the opinion of most neurosurgeons that end-to-end anastomosis is most effective. Studies of degeneration seem to indicate that the earlier the divided nerve is sutured, the better the chance of a good functional result. There is, of course, good clinical and experimental evidence to substantiate this view. However, during the recent war, research indicated

that delayed suture might offer better physiologic opportunities for regeneration of the nerve. Tissue cultures of regenerating nerves showed that proliferation of Schwann's cells and fibroblasts reaches its peak on the nineteenth to twenty-fifth days and then falls off to a level at sixty days after injury. At the peak there are forty times more cells than there are four days following injury. At the end of sixty days there are fifteen times the number. Further evidence shows that there is a maximal cellular activity of the central or proximal stump five or ten days after a nerve is sectioned. This indicates that delayed suture offers a better chance of successful regeneration than immediate suture. Insufficient

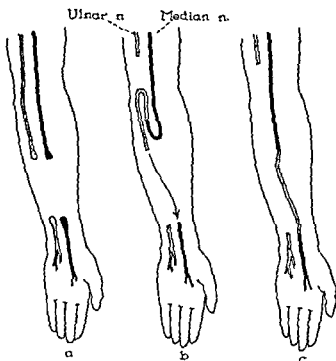


Fig. 394.—The ulnar pedicle type of graft to overcome a large defect in the median nerve in the forearm. (Craig in Walters-Lewis Practice of Surgery, published by W. F. Prior Company.)

time has elapsed since these observations were made to provide any clinical evidence to substantiate the laboratory data.

For the most part, nerve grafts have been unsuccessful. This, however, is not entirely true. Recently Shelden, Pudenz and one of us (C. S. M.) reported three cases in which a pedicle type of graft was used (fig. 394). In all three cases the median and ulnar nerves were damaged extensively. The ulnar nerves were used as a pedicle graft to fill the extensive defects in the median nerve. The ulnar nerve was divided at one stage of the operation proximal to the defects in the median and ulnar nerves in the forearm. At this procedure the end of the ulnar nerve graft at the point of surgical division was sutured to the

proximal end of the traumatically divided median nerve thus preserving the blood supply to the rest of the ulnar nerve which was left in its bed. At a second stage after the graft had theoretically obtained new blood supply from the growing portion of the median nerve and after there was sufficient evidence by Tinel's sign to indicate that the median nerve was transversing the ulnar graft, the lower portion of the ulnar nerve was freed up and sutured to the distal portion of the traumatically divided median nerve. The interval between the first and second stages was usually in the neighborhood of three months. The results in these cases were gratifying and indicated that this type of sacrifice of an already paralyzed nerve was justified to improve or to obtain function in a more important paralyzed nerve. The success of this procedure

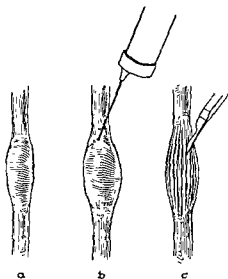


Fig. 395 —Methods of neurolysis injection of saline solution and splitting the fasciculi

is dependent on the preservation of the blood supply in the nerve graft by using the pedicle flap method.

Many injured nerves do not require resection of neuromas and suturing. These are the nerves which are physiologically disrupted by intrinsic neuromas due to neighboring injury. These nerves frequently recover after neurolysis. Neurolysis may be performed by injection of saline solution between the fasciculi of the nerve or by splitting the fasciculi with a razor blade (fig. 395). Sometimes the two methods are combined. The exact physiologic event that causes improvement in these cases is not completely understood. However, dramatic recoveries have been observed by many neurosurgeons who have used this procedure on large numbers of peripheral nerves.

Any paper dealing with the treatment of injuries to nerves would be incomplete without mention of concomitant causalgic syndromes which are so dramatically relieved by sympathectomy. The role of this type of surgery in relieving causalgia and increasing the blood supply to severely injured extremities cannot be minimized. Indeed, during the recent war, it played a major role in the treatment of the injured. The advance of this type of surgery was indeed a major contribution to war medicine.

REHABILITATION

Similarly the term "rehabilitation" appeared during the recent war associated with the work of the physical therapist, neurologic surgeon, orthopedic surgeon, plastic surgeon and vascular surgeon. The physiologist has added the electromyogram to the armamentarium useful in diagnosis of nerve lesions and for determination of the progress of recovery. The study of skin resistance is used to outline sensory disturbances. With these tools the physical therapist directs rehabilitation of the extremity. It is encouraging to see this type of work being carried on not only in the Navy, Army and Veterans Hospitals but also in the large civilian clinics and medical centers.

SUMMARY

Injuries to the peripheral nerves must be considered to rank with other related injuries to the extremity and adjacent structures. These, of course, include injuries of blood vessels, bones, tendons, muscles and viscera and particularly injuries of the thorax. An injury of a nerve without involvement of other structures is indeed rare. Consequently the treatment of nerve injuries is complicated and demands the full attention of many specialists including, in particular, the neurologic surgeon, vascular surgeon, orthopedic surgeon, general surgeon, physical therapist and all the other workers in the field of basic sciences who have advanced the treatment of nerve injuries through their untiring research.

To understand nerve trauma requires knowledge of three types of injury that occur to nerves. The first type is complete anatomic division of the nerve. The second is a lesion in continuity in which the supporting structure of the nerve is preserved but there is such a disturbance of the nerve fibers that true degeneration occurs peripherally. The third type is the transient physiologic block due to a minimal lesion of the nerve from which complete and rapid recovery often occurs. Clinically these types of injuries result in loss or perversion of function either in the afferent or efferent components of the nerve or both.

Generally speaking, immediate surgical treatment for a divided nerve

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TENOSUSPENSION OPERATION FOR RECURRENT OR HABITUAL DISLOCATION OF THE SHOULDER

MELVIN S. HENDERSON

In the August, 1943 issue of *The Surgical Clinics of North America*, I presented an article on the tenosuspension operation for recurrent dislocation of the shoulder. The present article is based on a follow-up of the patients reported on then, along with a report on additional patients.

My colleagues and I have performed the tenosuspension operation, up to June 7, 1947, on 68 patients, 6 having bilateral operations, making a total of 74 shoulders operated on. We have been unable to trace 2 patients, cutting the number of operations on traced patients to 72.

A complete review of the literature on the subject of recurrent dislocation of the shoulder, while interesting, would not be pertinent at this time. However, I shall refer briefly to some of the more recent articles on the subject. Unfortunately, many of the reports in the literature describe some particular type of operation with a report of a few cases in which too short a time has elapsed to evaluate the method advocated. The majority of the patients who form the background of this paper have been traced over long periods of time, some as long as twenty-five years.

Basing my expectations upon our experience with this operation up to 1943, when 90 per cent of the operations were successes, the end results to date have not been as satisfactory as I had hoped. This, however, is all the more reason why my colleagues and I should report our cases up to date. We have classified our end results as "successes" or "failures," no intermediate status being considered. It is quite true that some of the patients whose operations were put down as failures are much improved and that some have had only 1 dislocation, sometimes due to severe trauma, and no subsequent dislocation over a long term of years. These patients are well-satisfied. However, if a shoulder has been dislocated once after the tenosuspension operation, we have simply classified the operation as a failure.

In at least partial explanation of the increased percentage of failures, it is only fair to state that in more recent years we have operated upon a number of patients in whom the dislocations were associated with epileptic attacks, the initial dislocation not being traumatic in origin. All of those who have had any experience with recurrent dislocations of the shoulder know that recurrence after operation is more apt to occur in epileptics than in nonepileptics. Out of a total of 68 patients on whom

I am reporting, 18 were epileptics, 4 of whom had bilateral operations, making a total of 22 operations on epileptics. In this communication, I shall report on the results of the entire group, including the epileptics and, in addition, report the results in the epileptics alone and the results in those who had no epilepsy.

The medical literature is replete with descriptions of a great variety of operations for recurrent dislocations of the shoulder. There are reasons for this. Recurrent dislocations of the shoulder are none too common, and it is rare that any one surgeon has a large experience. Also, the recording of long-term end results has been meager, so that the inexperienced surgeon, looking to the literature for guidance, up to the present time, has had very little actual data on which to base his choice. The operations fall more or less readily into four main groups: (1) those in which the attack is chiefly upon the capsule, the aim of which is to reinforce and strengthen the capsule, (2) those wherein the attack is upon the muscles concerned with the function and stability of the shoulder joint, (3) those in which an attempt is made by transplantation of bone to form a bone block anteriorly and (4) those wherein the attempt is made to provide new ligaments, either intracapsular or extracapsular. Naturally, there is a certain amount of overlapping in some of the operations described, and two types may be more or less combined.

CAPSULORRHAPHY

The capsule of the shoulder joint is necessarily a very lax affair. Thomas early advocated capsulorrhaphy. On the whole, this operation has not, in the past, given satisfactory results. The tendency has been to swing away from capsulorrhaphy to some other procedure, but this trend has been reversed lately because of the increasing favor in which Bankart's procedure is held. Without doubt, the earlier types of capsulorrhaphy were not as thorough as they should have been. The type of capsulorrhaphy attracting the most attention today is the Bankart operation, based upon his claim that a slipping or dislocation of the labrum glenoidale is the fundamental lesion and that if the labrum be replaced into position, a cure results. Magnuson's operation is also a capsulorrhaphy, except that he combines with his capsulorrhaphy, transplantation of the subscapularis tendon from the lesser tuberosity to the greater tuberosity.

MUSCLE OPERATIONS

The pectoralis major, the latissimus dorsi and the teres major are adductors and internal rotators. They are inserted into the upper third

of the shaft of the humerus. When the arm is abducted from the side, these muscles are taut, particularly the pectoralis major, which is attached to the anterior lip of the bicipital groove and quite close to the head of the humerus. This muscle tends to pull the head of the humerus down and forward, and is very powerful. The latissimus dorsi and the teres major tend to pull down rather than forward when the arm is in abduction and internal rotation, and the head of the humerus is thrown forward against the anterior part of the capsule. The muscles that hold the head backward are the supraspinatus, the infraspinatus and the teres minor, all external rotators and abductors. They coalesce laterally and then go forward to be attached to the greater tuberosity at the upper part of the humerus just lateral to the head and a bit posterior. These muscles do not form an intimate part of the capsule. The subscapularis muscle is an internal rotator; it arises from the under surface of the scapula and winds around forward to become attached to the lesser tuberosity on the anterior surface of the upper portion of the humerus and is an intimate part of the capsule.

An operation having to do with muscles that attained considerable favor, was the Clairmont operation, the objective of which was to make a muscular sling to support the head of the humerus. To do this, Clairmont, through a long posterolateral incision, dissected the posterior one fourth or one fifth of the deltoid muscle, freed it at its insertion, lifted it upward and then brought it through the axilla by way of the quadrilateral space, pulling it up forward and attaching it to the coracoid process and the short head of the biceps. Our experience with this operation was not good, although in the cases in which it was successful, there was full motion.

TRANSPLANTATION OF BONE

Oudard's operation had to do with splitting the coracoid process longitudinally and sliding the half downward, markedly lengthening it. Thus it would prevent the dislocation forward of the head of the humerus. Most of the bone-grafting operations have to do with deepening of the glenoid fossa by placing a bone block at the antero-inferior margin of the glenoid fossa. Such operations have been described by Eden, Speed and Palmer. I have had no experience with the bone-grafting procedures but the reports, particularly a late one by Palmer, are very encouraging.

LIGAMENTOUS REINFORCEMENT

Operations employing ligamentous reinforcement vary in character. Joseph in 1917 described an intra-articular procedure wherein he used

strip of fascia lata, attaching it to the head of the humerus through drill openings and to the upper margin of the glenoid fossa in such a manner as to make a suspensory ligament. No appreciable number of cases were ever reported.

Gallie and Le Mesurier⁴ in 1927 described a procedure whereby they used fascia lata to make a check ligament which extended from the outer margin of the scapula just below the glenoid fossa across to the humerus well up in the upper one third, the object being to lessen the range of abduction and thus prevent further dislocations. In later reports they have elaborated upon this operation, making it in addition a thorough capsulorrhaphy. A recent report⁵ by them on 175 cases, in which only 7 failures occurred, is very encouraging. However, no definite statement as to the length of time of observation after operation is given, and apparently very few, if any, epileptics were included.

Nicola in 1929^{10, 11} reported upon the use of the biceps tendon, wherein he severed the biceps tendon in the lower end of the bicipital groove, pulled the tendon up out of the groove, and then after scarifying it placed it down through a channel that had been bored through the head of the humerus and that emerged in the bicipital groove. Many good reports came of this procedure early and it attained considerable favor, but as time went on more failures were reported. The idea is appealing, but one must remember that in only one joint in the body does nature use an intra-articular ligament for support. The so-called ligamentum teres in the hip joint has no ligamentous function at all. It merely carries blood supply to the head of the femur. The one exception is the knee joint, and there a special bony arrangement is provided. Modifications of Nicola's operation have been recorded. One is the Roberts operation, wherein the long head of the biceps is lifted out of the bicipital groove, scarified and sewed back in the freshened bony groove. Thus, the ligament is extra-articular.

The tenosuspension operation that we have been doing at the Mayo Clinic since 1924 is an extra-articular operation, the attempt being to give extra-articular ligamentous support to the head of the humerus by providing ligaments that run from the acromion process to the region of the greater tuberosity (fig. 396). We have used the peroneus longus tendon, thereby justifying the name of tenosuspension. Fascia lata could and has been used by us in several cases, but the peroneus longus tendon is stronger. Nicola's operation is in reality a tenodesis and is intra-articular. Our operation is a tenosuspension and is extra-articular entirely, a free graft being used to furnish new extra-articular ligaments.

The technic of the tenosuspension operation is simple. The patient is placed on the side, between sand bags, with the affected shoulder

uppermost. General anesthesia is used. The skin is prepared in the ordinary manner and the forearm and hand are wrapped in a sterile sheet so that the arm can be moved at will. The leg on the same side is prepared from the knee downward. One of two methods of incision in the shoulder may be used: 1. The saber type of incision may be made whereby the skin can be reflected away from the area to be exposed. 2. Three or four small incisions, for example, two in front and one in back, may be used; particularly in women the smaller the scars, the

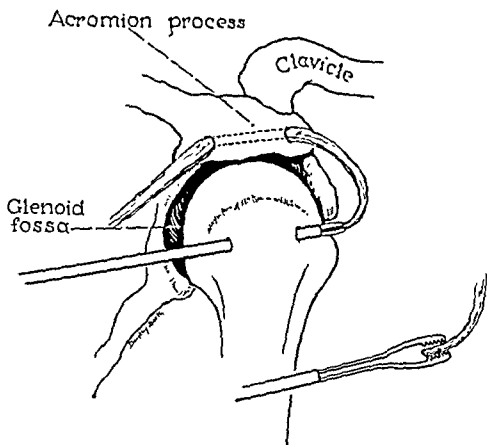


Fig. 396.—Tendon being routed through the drill holes by means of a Macey tendon puller.

better satisfied the patients will be. Holes are then drilled through the acromion process and through the upper end of the humerus, lateral to the joint line, about the region of the greater tuberosity (fig. 396). Extreme care must be taken that the drill used should not be too large for the size of the piece of tendon to be inserted. If the hole is too large and roomy the tendon may fail to grow fast to the bone, and when movement is begun it will slide back and fourth in the drill hole. Thus, the tendon will become worn and ultimately it will break. (A Kirschner guide wire is used and over this a cannulate drill is inserted.) To facili-

tate drawing the tendon through these rough, bony drill holes, we use a Macey tendon puller (fig. 396).

Through two incisions, one in the leg and one in the foot, such as are represented in figure 397, the tendon for the new ligament is obtained from the peroneus longus of the leg on the same side as the affected shoulder. The peroneus longus is exposed at the juncture of the lower

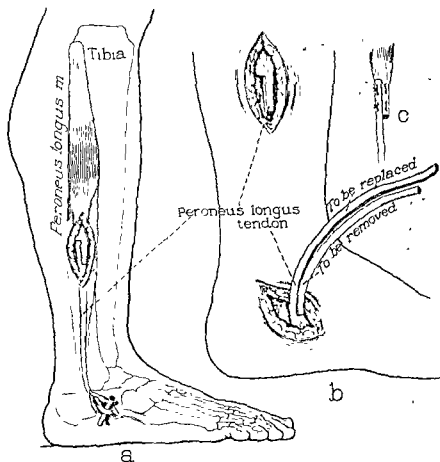


Fig. 397 —Method of obtaining piece of peroneus longus tendon (From Henderson, M.S.)

and middle thirds of the leg and is cut with a step (fig. 397). It is then loosened in its sheath by blunt dissection with a curved hemostat and is pulled out through a small wound on the outer edge of the foot, where the tendon turns to cross the sole of the foot. Half of the tendon is then removed for making the new ligament (fig. 397). The remaining portion of the tendon is then pulled back up through its sheath behind the external malleolus and the end is fastened to the upper end of the divided tendon. The wounds are closed in the usual manner.

After the operation on the shoulder the arm is held to the side for approximately ten days. After that, minor movement of the shoulder is permitted. Abduction to a right angle is not permitted for at least eight weeks. If the patient is subject to epileptic seizures, protection should be provided even more carefully and drugs should be used freely immediately after the operation to ward off seizures; this treatment should be kept up for four to six months.

The success of the operation depends on proper insertion of the free tendon transplant. The dissection must be carried through the heavy deltoid muscle down onto the periosteal layer of the bone so that the peroneus longus transplant is deeply placed and lies directly along the bone, thus providing a snug fit. Also, the tendon should be carefully scarified. If the dislocation is of the directly anterior type and is easily produced, it is doubtful if this is the operation of choice. It may well be that an anterior bone block should be used. Neither is the operation suitable for the shoulder that tends to become dislocated posteriorly. In such instances, posterior capsulorrhaphy is the operation of choice and is satisfactory. It is possible that a certain percentage of the dislocations which occur among patients with epilepsy are directly anterior; in those cases if tenosuspension is used, the tendon, especially the posterior sling, must be deeply and snugly placed, as has been mentioned.

REPORT OF DATA ON 68 PATIENTS

In the August, 1943, number of *The Surgical Clinics of North America*, I reported on 51 patients on whom my colleagues and I operated by the tenosuspension method for recurrent dislocation of the shoulder. Up to June 7, 1947, we had operated upon 17 more patients, bringing the total to 68 (table 1). There were 55 males and 13 females. The average age was 28 years; the oldest patient was 64 years and the youngest was 16 years. There were 74 shoulders operated upon. There were 7 patients who had dislocations of both shoulders, 6 of whom had bilateral operations. The average duration of the recurrent dislocations was 5.2 years; the longest was 20 years and the shortest was 6 months. The number of dislocations per patient varied but several had had 100 or more. The results of 72 operations were definitely known; 2 patients could not be traced. In the series there were 18 epileptic patients, 4 of whom had both shoulders operated upon, giving a total of 24 operations with 12 successes (55 per cent). In the nonepileptics 50 operations in traced patients, with 39 successes, giving the group as a whole, including those with epilepsy, there were 72 operations in traced patients, with 39 successes (55 per cent), none of the patients being observed for half years and some being followed for more than

TABLE 1

DATA ON 68 PATIENTS WHO UNDERWENT THE TENOSUSPENSION OPERATION
FOR DISLOCATION OF THE SHOULDER

Case	Age and Sex	Occupation	Initial Injury	Dislocations Before Operation	Shoulders Affected	Date of Operation	Years of Observation	Result
1*	31M	None	Epileptic seizure	30	Left	6-12-24	23	Success
2*	33F	Housewife	Unknown	32	Left	4-30-25	23	Success
3	32F	Housewife	None	12	Right	9-11-25	14½	Success
4	26M	Tool dresser	Football	15	Left	8-19-26	10	Success
5	23M	Student	Unknown	Many (?)	Right	4-5-27	7½	Success
6	22M	Prize fighter	Boxing	7	Both	(L)4-9-28	20½	Success
7	39F	Dietitian	Tennis	Many (?)	Right	8-14-28	18	Success
8	23M	Machinist	Boxing	15	Left	12-6-29	4	Success
9	37F	Sister of Charity	Fall	10	Right	8-15-29	19	Success
10	26M	Cabinet maker	"	9	Right	10-4-29	5	Success
11	38M	Oil driller	Fall	20	Left	3-6-30	4½	Success
12*	26M	Interior decorator	Fall	22	Left	3-12-30	8	Failure
13	21M	Student	Baseball	12	Right	6-12-30	1	Failure
14	24M	Laborer	Fall	2	Right	6-28-30	4½	Success
15*	29M	Student	Epileptic seizure	25	Right	10-17-31	11	Failure
16†	21M	Student	Football	113	Right	11-17-31	3	Success
17	39M	Dentist	Diving	20	Left	12-7-31	11	Success
18	27M	Time-keeper	Boxing	30	Left	6-8-33	6	Success
19	26F	Housework	Fall	Many (?)	Right	11-28-33	14	Success
20	50M	Miner	Pushing tram car	Right 3 Left 2	Both	(R)1-13-34 (L)2-9-34	5 5	Success Failure
21	19M	Student	Fall on arm	40	Left	3-21-34	5½	Success
22	24M	None	Tumbling	10	Right	6-20-34	8	Success
23	17M	Student	Football	3	Left	8-3-34	3	Success
24	20M	Rancher	Boxing	30	Right	12-5-34	5	Success
25*	23M	Drugstore clerk	Epileptic seizure	3 a day	Left	1-18-35	7½	Success

TABLE 1—Continued

Case	Age and Sex	Occupation	Initial Injury	Dislocations Before Operation	Shoulders Affected	Date of Operation	Years of Observation	Result
20	23M	Student	Football	Many	Both	(R)1-29-35 (L)2-11-35	3 3	Failure Success
27	20M	Student	Fall	20	Left	5-8-35	8	Success
28	16F	Student	Fall from bicycle	10	Right	6-24-35	9	Success
29*	23M	Laborer	Fall from horse	4	Right	11-12-35	11	Success
30	22M		Fall on ice	5	Right	12-5-35	7	Success
31	21M	Chemist	Handball	9	Right	7-4-36	6	Success
32	24M	Attorney	Fall	11	Right	10-8-36	10	Success
33	25M	News-stand	None	?	Right	1-26-37	1	No information
34	21M	Hockey player	Hockey	20	Right	5-20-37	5	Success
35	22M	Truck driver	Boxing	3	Left	9-4-37	2	Success
36	36M	Physician	Fall	Many	Right	10-1-37	5	Success
37	23M	Student	Hockey	10	Left	7-6-38	10	Failure
38	19M	Student	Basketball	11	Right	10-5-38	4	Success
39*	19M	Student	Epileptic seizure	100	Right	1-7-39	8	Failure
40†	24M	Student	Epileptic seizure	Many	Both	(R)7-3-39 (L)10-28-40	3 2	Success Success
41	20F	Student	Fall	100	Right	6-27-40	6	Failure
42	30M	Store clerk	Unknown	60	Left	6-3-41	7	Success
43	34M	Farmer	Thrown from horse	40	Left	6-18-41	1	Success
44	29M	Student	Football, sking	12	Right	6-27-41	7	Success
45	32M	Teacher	Football	300	Right	6-5-41	2	Success
46	21F	Domestic	Unknown	4	Left	12-1-41	1	Success
47	22M	Student	Auto accident	Many	Left	2-5-42	6	No information
48*	22M	Farm laborer	Epileptic seizure	35	Left	2-14-42	6	Failure
49	20F	Student	Fall	4	Left	2-18-42	6	Success
50*	21F	None	Epileptic seizure	100	Both	(L)5-13-42 (R)4-5-44	6 4	Success Success

TABLE 1

DATA ON 68 PATIENTS WHO UNDERWENT THE TENOSUSPENSION OPERATION
FOR DISLOCATION OF THE SHOULDER

Case	Age and Sex	Occupation	Initial Injury	Disloca- tions Before Operation	Shoul- ders Affected	Date of Operation	Years of Observ- ation	Result
1*	31M	None	Epileptic seizure	30	Left	6-12-24	23	Success
2*	23M	Housewife	Unknown	32	Left	4-30-25	23	Success
3	32F	Housewife	None	12	Right	9-11-25	14½	Success
4	26M	Tool dresser	Football	15	Left	8-19-26	10	Success
5	21M	Student	Unknown	Many (?)	Right	4-5-27	7½	Success
6	22M	Prize fighter	Boxing	7	Both	(L)4-9-29	20½	Success
7	39F	Dietitian	Tennis	Many (?)	Right	8-14-29	18	Success
8	23M	Machinist	Boxing	15	Left	12-6-28	4	Success
9	31F	Sister of Charity	Fall	10	Right	8-15-29	19	Success
10	26M	Cabinet maker	"	9	Right	10-4-29	5	Success
11	36M	Oil driller	Fall	20	Left	3-6-30	4½	Success
12*	26M	Interior deco- rator	Fall	22	Left	3-12-30	6	Failure
13	23M	Student	Baseball	12	Right	6-12-30	1	Failure
14	24M	Laborer	Fall	2	Right	6-29-30	4½	Success
15*	29M	Student	Epileptic seizure	25	Right	10-17-31	11	Failure
16†	21M	Student	Football	113	Right	11-17-31	3	Success
17	39M	Dentist	Diving	20	Left	12-7-31	11	Success
18	27M	Time-keeper	Boxing	30	Left	6-8-33	6	Success
19	26F	Housework	Fall	Many (?)	Right	11-28-33	14	Success
20	50M	Miner	Pushing tram car	Right 3 Left 2	Both	(R)1-13-34 (L)2-9-34	5 5	Success Failure
21	15M	Student	Fall on arm	40	Left	3-21-34	5½	Success
22	24M	None	Tumbling	10	Right	6-20-34	8	Success
23	17M	Student	Football	5	Left	8-3-34	3	Success
24	20M	Rancher	Boxing	30	Right	12-5-34	5	Success
25*	25M	Drugstore clerk	Epileptic seizure	5 a day	Left	1-18-35	7½	Success

years, and late failures have been faithfully included in this series. Too often a reported series has not been followed over a sufficient length of time to justify the claims made. On review of the literature, I believe that some of the bone-block procedures should be more seriously considered. It is quite clear from our experience that the tenosuspension operation in epileptics does not give good enough results to justify its use according to the present procedure. Some other more radical procedure that may entail more restrictive mobility of the shoulder than does the tenosuspension operation probably should be used. While the majority of the failures occur within the first year or two after the operation, nevertheless, failure may occur five years or later after the operation. This series is not large and a few cases either one way or the other alter the percentage of successes and failures materially. This experience, however, is sufficient to establish the tenosuspension operation as a worth-while fundamental procedure, as stated previously.

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TRAUMATIC DEFECTS OF THE NOSE AND CHEEKS

JOHN B. ERICH

Every traumatic loss of tissue about the nose and cheeks produces a defect which always is conspicuous and often is unsightly. It is a rare exception to find a person with such a defect who surveys it with indifference. On the contrary, practically everyone afflicted with a loss of tissue in the regions under discussion is extremely concerned with the deformity and is particularly eager to obtain some form of plastic repair. Any analysis of available surgical technics, which are designed to correct or improve such defects, is lacking in completeness if it neglects to include methods both of immediate care and of delayed restoration.

When a small portion of skin about the nose or cheeks is missing after a recent injury, the margins of the defect occasionally can be deeply undermined by sharp dissection, which permits satisfactory approximation of the edges of the wound. When the loss of tissue is of any appreciable size, however, such treatment can result only in much distortion and disfigurement; in these cases, the immediate application of a skin graft is an excellent procedure, provided that gross contamination is not evident. If the denuded region is not too large, a dissected dermal graft from the posterior auricular region is desirable because the color and texture of the skin obtained in this situation very closely resemble that of the face. However, when a large graft is required, one is forced to resort to the employment of a dissected or Thiersch transplant taken from the arm, thigh or trunk. The act of adapting a dermal graft to a region recently denuded of skin usually meets with considerable success, and thus scarring and distortion are prevented, which are inevitable when such a wound is left to become epithelized spontaneously. In badly contaminated wounds, of course, skin grafting should not be considered. Instead, warm dressings should be applied and the transplantation of skin should be deferred until the infection has entirely disappeared.

In employing a free shave or full-thickness skin transplant, three factors contribute to the success of such grafting; these are asepsis, hemostasis and immobilization of the graft. In addition to a firm external dressing, my colleagues and I usually leave the sutures which anchor the graft to the margins of the defect very long so that they can be tied over a bulk of gauze or cotton. This technic is a great aid in the immobilization of the graft and in the prevention of subsequent hematomas. Full-thickness grafts are inlay transplants and must be

orbital flap and the midline sickle-shaped flap are reserved mainly for total reconstruction of the nose or for repair of the nasal tip.

The sickle-shaped temporal flap (fig. 407) is the most useful of the forehead flaps for repair of partial defects of the nose and cheeks. This graft gives a very good cosmetic result and leaves less visible scarring on the forehead than is produced by any of the other forehead flaps. This sickle-shaped temporal flap can be extended back into the scalp to give it any desired length; it makes use of the bay of skin on the side of the forehead which is the most inconspicuous area on the forehead. When this flap is transferred to a defect, and this applies to all of the forehead flaps, the denuded donor surface on the scalp and forehead is covered with a

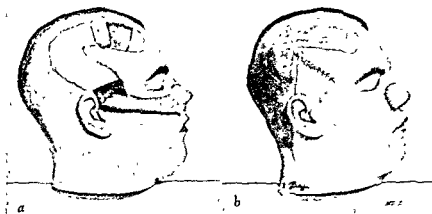


Fig. 407.—Sickle-shaped temporal flap. The flap has been brought to repair the denuded surface on the scalp has been covered

thin shave skin graft. Such a free graft protects the denuded surface and prevents infection and the development of granulations and scar tissue. Three weeks after the flap has been transferred, it can be cut across just above the reconstructed area and the unused part returned to the scalp. Before the pedicle can be sutured back in the original donor site, the underlying free skin graft must be excised, leaving only a small portion on the forehead. Peculiarly enough, the donor area of a sickle-shaped temporal flap tends to shrink and contract while the pedicle flap, after it has been transferred, tends to elongate. Consequently, when the unused part is returned to the scalp, its length appears to be greater than it was originally. As a result, a very small amount of free shave skin graft is left on the forehead.

A temporo-frontal flap has a limited degree of usefulness but is to be

orbital flap. As a matter of fact, the forehead usually will afford no more than just enough tissue to construct a whole nose without including hair-bearing skin.

When merely the lower third or tip of the nose is lost, the midline sickle-shaped flap (fig. 411) is ideal because only a small amount of skin free of hair is necessary to reconstruct the lost portion of the nose. Under such circumstances, the midline sickle-shaped flap is to be recommended since it will leave less visible scarring on the forehead than would a loop-shaped supra-orbital flap.



Fig 410 —a, Defect involving a loss of the greater part of the nose. b, Nose reconstructed by means of a loop-shaped supra-orbital flap

These two types of forehead flaps require considerable time in preparation and several stages in elevation in order to insure an adequate blood supply. The edge of the distal portion of the flap always is folded as is illustrated in figure 412 to form a columella and nostrils. By this process the lower half of the newly constructed nose is lined with skin. Whether or not the upper half needs to be lined with a free skin graft depends on the size of the nasal defect. If so, this free graft should be applied to the undersurface of the flap in the first stage of its elevation.

A reconstructed nose or nasal tip should be made somewhat larger than necessary to allow for subsequent shrinkage. Three to six months after the nasal reconstruction has been completed, the excess fat should be excised to effect a better contour. This can be accomplished by incising and undermining the skin over the dorsum of the reconstructed

tube flaps do have the disadvantages previously described, they also have the advantage of supplying enough tissue for almost any type of reconstruction about the face and supply both fat and skin. Occasionally, the loss of an entire cheek requires more tissue than could ever be

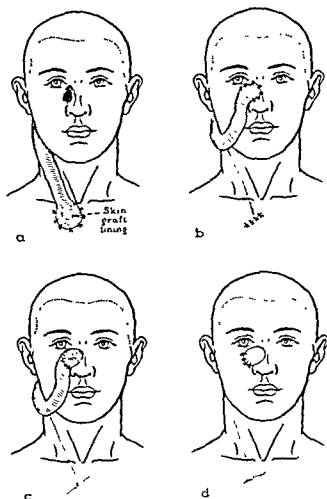


Fig 413.—Cervical tube flap. *a*, The lower extremity of the tube flap, which has previously been prepared, is partially elevated and lined with a shave skin graft. The skin graft will form the lining for the reconstructed part. *b*, Ten days later, the lower end of the cervical tube flap is elevated and attached to the margins of the defect on the right side of the nose and cheek. *c*, Two weeks later, the tube is cut halfway across at the outer margin of the defect. This incision is sutured. *d*, One week later, the unused part of the tube is detached from the reconstructed part and also from the neck and discarded.

procured through a flap on the forehead and scalp, and in these situations a tube flap on the trunk becomes essential. The one great advantage in a tube flap on the neck or chest or trunk lies in the fact that scarring at the donor site is not visible when the patient is clothed. Under ordinary circumstances, only one end of a tube flap is employed for reconstruction. However, it is not uncommon to employ one end of the tube

flap for repair of that portion of the defect involving the nose and the other end of the flap for that portion on the cheek.

Cervical and clavicular tube flaps can be considered together because they are employed for the same purpose. They supply tissue for smaller defects about the nose and cheeks. A cervical flap (fig. 413) has the advantage of reaching directly to the defect but has the disadvantage of leaving visible scarring on the side of the neck when the patient is clothed.

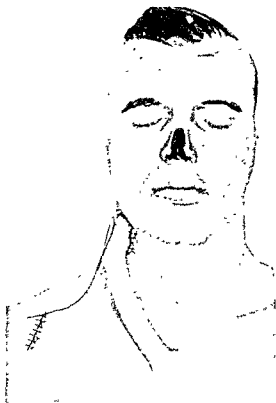


Fig. 414 —Clavicular tube flap for the repair of a nasal defect. The tube flap is elevated just below the clavicle. Four to six weeks later, the mesial end is detached and brought up to the nasal defect. This form of migration is necessary for a short tube in order that it can be elevated to the facial defect.

On the other hand, a clavicular tube flap (fig. 414) is too short to reach directly to the defect; one end must be attached to the side of the neck as an intermediary stage before the other end can be detached and transferred for the reconstructive process. In consequence, a clavicular tube flap requires an extra four weeks' time in preparation. It has the advantage, however, of not leaving visible scarring when the patient is clothed, as does the cervical tube flap.

AVULSION FRACTURE WITH NONUNION OF THE ANTERIOR TIBIAL SPINE TREATED BY FIXATION WITH BEEF-BONE SCREW

Report of Case

HENRY W. MEYERDING AND A. CYRIL WALSH

Our interest has recently been directed to this condition by the return, for a recheck, of the patient to be reported on in this paper. To our knowledge, no case of nonunion of the tibial spine has been reported in which the ununited fragment of several years' standing has been replaced and fixed by means of a beef-bone screw. While this condition was reported in the latter part of the nineteenth century, the first case in which open replacement and fixation of the fragment was carried out was reported in 1907 by Pringle. With the increasing use of roentgenograms of injuries of the knee joint, the condition is being more frequently recognized.

The anterior cruciate ligament is attached to the intercondylar area immediately anterior to the tibial spine. Avulsion of the anterior cruciate ligament at its inferior attachment may involve avulsion of the anterior tibial spine. Fractures of the spines have been classified into various categories depending on the extent of the injury and the spines fractured. For practical purposes with regard to treatment, it is important to know if the bony attachments of the anterior cruciate ligament and the menisci are disturbed and if there is enough displacement of the bony fragment to block movement of the knee joint.

Blaisdell carried out a series of experiments on cadavers, in which he demonstrated that force applied in the direction to cause rupture of the anterior cruciate ligament would cause avulsion of the intercondylar eminence. Fractures of the spines themselves may be caused by forceful torsion of the knee and shearing off of the spines by one or the other femoral condyle. The more serious avulsion fractures are caused by injuries such as might cause a rupture of the anterior cruciate ligament.

The treatment of the condition is fairly standardized. Jones and Smith advocated closed reduction and manipulation into full extension, and fixation in this position. If the fragments blocked full extension, the joint should be opened and the fragments excised. Venable excised the fragments in 2 cases. Lee reported 4 cases in which open reduction was performed and the fragments replaced and fastened by suture passed through drill holes extending to the region of the tibial tubercle. Anderson recommended open reduction and fixation of the fragment in avulsion fractures. In simple fractures of the spines, fixation in hyperextension would suffice. MacAusland advocated open reduction by means of a

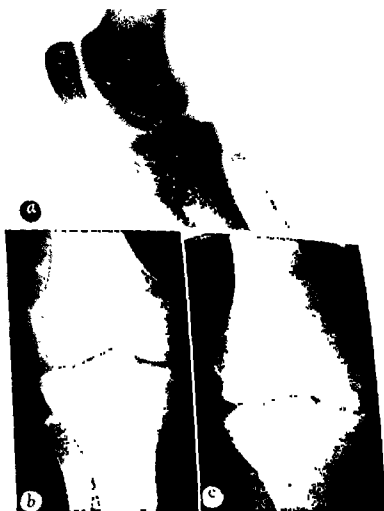


Fig. 417.—*a*, Preoperative lateral view showing avulsion of a part of intercondylar eminence with the tibial spine. *b*, Postoperative anteroposterior view showing avulsed fragment replaced and held in position with a beef-bone screw. *c*, Anteroposterior view twelve years after operation, showing absorption of screw and union of the fracture.

of loose bone with the anterior cruciate ligament attached was observed. The fragment, $\frac{1}{4}$ by $\frac{1}{4}$ by $\frac{1}{4}$ inch (1.3 by 1.3 by 0.6 cm.), was present, as well as four pieces of bone which were lying loose; the largest of the latter was $\frac{1}{4}$ by $\frac{3}{8}$ in (0.6 by 0.5 cm.) and this together with the smaller pieces was removed. The fragment of bone on which the cruciate ligament was inserted was freshen-

the cavity from which it had been pulled loose was gently curetted, the fragment was replaced in its normal bed and a beef-bone screw was inserted which held the fragment and cruciate ligament firmly in position (fig 417, b). The knee was moved from full extension to 80 degrees of flexion without displacement of the replaced fragment. There was roughening of both condyles in the region of the intercondylar notch which was secondary to irritation from the loose body; the semilunar cartilages appeared to be intact. The convalescence was uneventful and on the twenty-fourth postoperative day the cast was removed and the wound was found healed. The sutures were removed and a cast re-applied from the ankle to the groin with the knee in extension. The patient was dismissed on July 1, 1935, and advised to bear some weight on the leg. She returned on August 7, 1935 (two months postoperatively), at which time the cast was removed and roentgenograms were taken. The posterior half of the cast was then applied as a part time splint, and she was advised to have quadriceps exercises and to massage the knee.

The patient continued to have some pain in the knee and returned to the Clinic a year later. The range of motion was 65 degrees of flexion from full extension. The knee was stable in all directions. The roentgenograms showed union of the fragment and absorption of the bone screw. She received physical therapy for four weeks and the flexion increased to 90 degrees.

Three years postoperatively, she was seen again, at which time she had no complaints except that flexion was limited to 90 degrees. She could walk up and down stairs without difficulty. There were some hypertrophic changes now seen in the roentgenograms of the knee. Twelve years postoperatively, the patient was seen again and at this time she had no pain in the knee. There was full extension and 75 degrees of flexion. Stability was good. The roentgenograms showed osteoarthritis in the knee joint (fig 417, c).

COMMENT

It has been our practice to treat avulsion fractures of the tibial spine by rest and plaster cast with the knee in full extension. In case of an extensive comminuted fracture and failure of union, we believe that an open reduction and internal fixation is advisable in order to remove loose fragments of bone and firmly fix the ununited tibial spine to the tibia. At the time of operation, six years after the fracture, there was already evidence of roughening in both condyles of the femur; subsequent hypertrophic arthritic changes with lack of full flexion were anticipated and discussed with the patient postoperatively.

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SPONTANEOUS AND TRAUMATIC LYMPH FISTULAS

Data on 40 Cases

EDWARD S. JUDD, JR. AND JAMES T. NIX

Recent advances in physiology have broadened our appreciation of lymph function and lymph loss. The development of inguinal lymph fistulas in 2 postoperative patients on the service of one of us (E. S. J.) stimulated our interest and prompted this study of a much neglected surgical complication. Detailed reports of these 2 cases follow. The case numbers correspond to those in the tables.

REPORT OF CASES

CASE 39.—A 43-year-old housewife was admitted to the hospital for the repair of bilateral femoral hernias. There was bilateral enlargement of the inguinal nodes, the nature of which remained obscure. Biopsy of these nodes at the time of bilateral femoral herniorrhaphy revealed inflammatory tissue. On the eighth postoperative day, the dermal sutures were removed. In probing a fluctuant swelling beneath the left femoral incision, approximately 100 cc. of a clear, light yellow liquid was evacuated. The total protein content of this fluid was 3.8 gm. per 100 cc. yet it failed to clot on standing. A similar collection was noted beneath the right femoral incision. The daily drainage gradually lessened in volume and finally ceased in seven weeks. This annoying leakage of lymph ran its own course and seemed refractory to treatment.

CASE 40.—A 72-year-old woman was admitted to the hospital with a diagnosis of kraurosis vulvae. Six months prior to her initial clinic visit, she had received eleven roentgen treatments for the same condition. Vulvectomy and dissection of the left inguinal nodes were performed at the clinic. The operative specimen, examined by frozen section technic, was diagnosed as melano-epithelioma of the left side of the vulva with metastatic spread to one inguinal node on the left. On the ninth postoperative day, the dermal sutures were removed and the incision was probed, with the release of 200 cc. of a clear, pink fluid. The volume of drainage was estimated as 100 to 200 cc. daily for the first week. Drainage continued for more than a month. The fluid contained 4.1 gm. of total protein, 2.5 gm. of albumin, 1.4 gm. of globulin and 0.24 gm. of fibrinogen per 100 cc., yet it failed to clot on standing. Conservative treatment had little effect on the duration or severity of this complication.

REVIEW OF PERTINENT LITERATURE

Function of Lymph.—The investigations of Starling, in 1894 and Drinker¹¹ in 1946 have done much to establish the role of lymph in the body economy. They said that the degree of concentration of lymph protein is related to the capillary permeability of the part or organ drained,

and maintained that the chief function of lymph was the removal of excess blood proteins from the tissues.¹⁴ Furthermore, they showed the relationship of water balance and edema to this function and its derangement. In addition to a role in salvaging protein, the lymphatic circulation has been conceded a role in the extrahepatic origin of globulin. Blood protein is supplemented with globulin that is formed in the lymph nodes^{12, 31} and carried by the lymphocytes.^{23, 27} Antibodies⁵ and enzymes³⁵ have been reported in a concentration proportional to the protein content of the particular sample of lymph. The protein of intestinal lymph is thought to aid in the emulsification of fat.¹¹ The lymphatics of the liver are believed to be a conduit for both newly formed and stored protein.¹¹ Intestinal lymph becomes chylous in the fat-fed animal, indicating its role in the absorption and transport of neutral fats, fatty acids and esters.³⁵

Circulation of Lymph.—Certain cold-blooded animals, like the frog, have lymph hearts to assist in the movement of lymph.¹² By contrast, in man the lymphatic circulation is rudimentary, and many factors combine forces for the transport of lymph through the valved lymphatics; these factors include arterial pulsations, muscular activity, intestinal peristalsis and changes in intra-abdominal and intrathoracic pressure. In addition, the rate of lymph flow varies with age,¹² size,¹² hydration,⁴⁰ exercise,¹⁰ digestion,¹⁰ anesthesia,³⁷ hemorrhage,²¹ hypoproteinemia,⁴⁰ venous and arterial pressure,²¹ shock,³⁰ anoxemia³³ and so forth.

Figure 418 illustrates the pattern of the subdiaphragmatic lymphatics and the blending of visceral, parietal and peripheral lymph in the cisternal pool. The cisternal pool is evacuated via the thoracic duct. The liver and intestines contribute 95 per cent of the volume of thoracic duct lymph. As the opportunity to collect thoracic duct lymph in man presupposes disease or laceration of the duct and its environment, data on the rate of lymph flow in the thoracic duct of man are more likely to represent values in disease than values in the normal. Nevertheless, exceptional circumstances allowed Crandall and co-workers in 1943 to study thoracic duct lymph from a patient hospitalized one hour subsequent to a superficial neck injury. In carefully controlled studies, the rate of flow averaged 0.93 cc. per minute, was unaffected by skeletal muscular activity but showed a three-fold increase after meals. This patient still registered a weekly weight loss of 5 pounds (2.3 kg) when she was on a high caloric, high protein diet.

Retrograde Flow of Lymph.—The main lymphatic trunks are connected by a maze of interlacing collaterals. With lymphatic obstruction, the circulation of lymph may be retrograde and paradoxical.^{20, 25, 29, 36} In this connection, Blalock and co-workers in 1936⁶ and 1937⁷ demonstrated the enormous regenerating capacity of the lymphatics. Blalock and co-

workers⁷ were successful in blocking the abdominal lymphatics in only 3 of 52 dogs. The remaining animals gave evidence of a rerouting of subdiaphragmatic lymph through collateral channels and lymphaticovenous communications. Freeman in 1912 expressed the belief that these communications were a normal part of the lymphatic system. Lymphatic obstruction may be produced by the repeated injections of irritants.^{12, 14} With stasis of lymph, there is marked growth of fibrous tissue²¹ and a rise in the protein content of this static lymph.

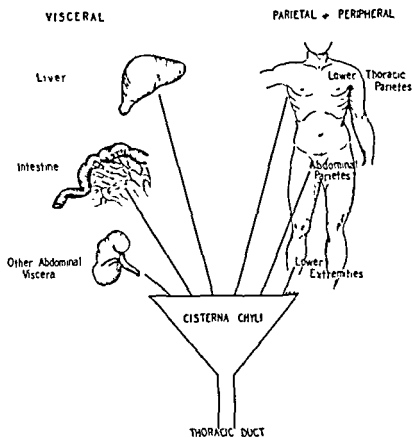


Fig. 418.—Cisterna chyli. Diagrammatic representation of the collection, blending and evacuation of subdiaphragmatic lymph.

Lymph Fistula.—This complication has received little consideration but has been given many names such as lymphorrhagia⁹ and lymphorrhea.¹⁸ It is a recognized complication of filarial elephantiasis with lymphatic obstruction²⁵ and has been reported after accidental¹⁰ and surgical^{2, 15, 25, 42} trauma to the thoracic duct. In animals, lymph fistulas have frequently been produced but as yet have never been maintained for more than two weeks. From studies made on dogs, Howell in 1914 found a prolonged coagulation time for chylous thoracic duct lymph, and Brinkhous and Walker in 1941 discovered that specimens of thoracic duct lymph had lower values for fibrinogen and prothrombin than did control

specimens of plasma and hepatic lymph. Drinker and co-workers in 1934¹²⁻¹⁴ collected lymph from the extremities of dogs which had experimentally produced elephantiasis. This lymph had an increased protein content, as did specimens from 4 patients with elephantiasis. Drinker and Yoffey¹⁵ in 1941 found that the protein content of lymph from a cannulated lymphatic of the extremity of a human volunteer was approximately 1 per cent. Harkins and Schug in 1942 reported a fistula of non-chylous peripheral lymph from damaged inguinal lymphatics after ligation of a saphenous vein. Drainage of several hundred cubic centimeters per day diminished gradually and ceased spontaneously in three months. Allen and co-workers in 1945 observed this complication 15 times in 464 patients with interruptions of the femoral vein. The recent report by Fishback in 1947 of prolonged leakage of lymph from the operative site in 3 patients after ligation of the greater saphenous vein has attracted widespread attention. In these 3 cases drainage continued for three weeks, three months and fourteen months respectively.

The treatment of lymph fistulas depends largely on their cause, however, some principles in their prevention and management apply equally well to all types. Most current authors advise that an injured lymphatic be treated like any injured vessel by repair of the defect,¹ ligation of the lymphatic,² implantation of the lymphatic into a vein,³ or the application of "gelfoam"⁶ or oxyeel⁷ to the site of leakage. In addition, many writers^{1-9, 19} advise a tight closure of the overlying tissues without drainage and with a pressure dressing. Drunker and Yoffey in 1941 proposed that the treatment of lymph fistulas follow physiologic principles. As the liver and intestines make the main contributions to thoracic duct lymph, these authors would place the patient on a fat free diet and otherwise attempt to limit peristalsis. As lymph flow is at a minimum in a resting extremity, they would treat a lymph fistula in the inguinal region by elevating the leg and applying a compression dressing. In the event of a secondary procedure for repair of a lymph fistula, they suggested that the site of lymph leakage be localized by injecting a dye (T-1824, trypan blue) *into the tissues of the extremity on the involved side*. By way of prevention, Baronofsky in 1948 advocated routine ligation of the afferent inguinal lymphatics during dissection of the inguinal nodes.

PRESENT INVESTIGATION

The records of the Clinic were reviewed in the search for proved clinical instances of prolonged lymph leakage. It was our hope that a critical analysis of collected data on a series of cases might clarify the question of the cause, and simplify the problem of the diagnosis and treatment, of lymph fistula.

TABLE 1
SPONTANEOUS LYMPH FISTULAS: 18 SELECTED CASES ENCOUNTERED AT THE CLINIC
(1908 THROUGH 1948)

Case and Year	Age and Sex	Fistula*			Diagnosis	Remarks
		Site	Lymph	Duration		
1 1918	41F	R. leg	Clear	6 mo.	Lymphedema	A liter of drainage a day
2 1919	42F	L. leg	Clear, chylous	3 yr.	Lymphedema	Cured by Kondoleon operation ²⁵
3 1919	21M	L. thigh	Clear, chylous	10 yr.	Inflammatory lymphedema	Many lymphocytes and fat globules in fluid
4 1919	17M	L. thigh, L. leg	Chylous		Lymphedema	
5 1920	19F	R. axilla	Clear	1 mo.	Diffuse lymphangioma	Congenital. Recurrent lymphangitis. Cured by excision
6 1927	19M	Abdomen, scrotum, L. leg	Clear	8 mo	Inflammatory lymphedema	
7 1936	58F	L. kidney	Chylous	8 mo	Chyluria	Urine coagulated. Reported by Wakefield and Thompson, and Eusterman
8 1936	53M	L. kidney	Chylous	7 yr.	Chyluria	Urine coagulated. Total urinary lipoids, 0.975 gm. per 100 cc. Reported by Wakefield and Thompson
9 1939	24M	R. leg, R. toe	Clear	8 yr.	Congenital lymphedema	Recurrent lymphangitis
10 1942	23M	Scrotum	Clear, chylous	9 yr.	Simple lymphangioma	Recurrent lymphangitis. Cured by excision and fulguration
11 1943	35M	L. kidney	Chylous	4 mo.	Chyluria	
12 1944	35M	Abdomen, scrotum, penis, R. thigh	Clear, chylous	25 yr.	Diffuse lymphangioma	Cured by excision and skin grafting. Reported by Ferris and Holmes
13 1945	28F	R. labia, vagina, L. leg	Clear	23 yr.	Diffuse lymphangioma	Recurrent lymphangitis

TABLE 1—Continued

Case and year	Age and sex	Fistula*			Diagnosis	Remarks
		Site	Lymph	Duration		
1429F 1946		L leg	Clear	5 yr.	Diffuse lymph-angioma	Congenital lesion
1551M 1946		Both kidneys	Chylous	2 mo	Chyluria	Urine coagulated Total urinary lipoids, 0.077 gm per 100 cc.
1650M 1947		L kidney	Chylous	10 yr	Chyluria	Total urinary lipoids, 0.988 gm per 100 cc, total blood lipoids, 0.650 gm per 100 cc
1722M 1947		R thigh, L scrotum	Clear	10 yr	Simple lymph-angioma	
1829F 1947		R thigh, R leg	Clear	1 yr	Congenital lymph-edema	Recurrent lymphangitis

* Multiple orifices were present in each case

This report embraces data on 40 cases of lymph fistulas encountered from 1908 through 1948. These cases were gathered by screening records of a variety of diagnoses. As a result, some cases may have been missed; many more were discarded for lack of positive identification of the discharge as lymph. Furthermore, as one would suspect from the northern location of the Clinic, none of the lymph fistulas in this series occurred as a complication of filariasis. Consequently, since only these fistulas have been proved by pathologic examination of the lesion and chemical studies of the fluid exudate, only these cases have been selected.

Classification of Lymph Fistulas.—Lymph fistulas may be classified conveniently as to their mode of onset into spontaneous and traumatic types.

Spontaneous Lymph Fistulas (table 1).—There were 18 cases of this type in our series. In 17 of these the lesion was subdiaphragmatic, being located within the distribution of the thoracic duct. Each of these 18 fistulas had multiple orifices. The duration of the fistulas ranged from two months to twenty-five years. Lymph was clear in 8 cases, chylous in 6 and mixed in 4. The fact that in 10 cases there was chylous or mixed lymph drainage was evidence of the retrograde circulation of lymph. Of the 13 patients with lymphangioma or lymphedema, 8 gave a history of recurrent lymphangitis. Seldom did spontaneously occurring lymph fistulas close spontaneously. Rather, these fistulas tended to spread to

TABLE 2

TRAUMATIC LYMPH FISTULAS: 22 SELECTED CASES ENCOUNTERED AT THE CLINIC (1908 THROUGH 1935)

Case and Year	Age and Sex	Fistula				Diagnosis	Trauma
		Site	Lymph	Orifices	Duration		
19 1919	62M	L. side of neck	Clear, chylous	Single	2 mo.	Epithelioma of L. cheek. Metastasis to cervical nodes	Uneventful excision of epithelioma. Fistula followed excision of cervical nodes, May 3, 1919
20 1919	34F	L. leg	Clear	Multiple	4 mo.	Congenital lymphedema	Kondoleon operation ¹⁸ , July 24, 1919
21 1920	40M	L. side of neck	Chylous	Single	10 mo.	Pharyngo-esophageal diverticulum	Excision in two stages, Nov. 25, 1919, and Dec. 3, 1919. Spontaneous closure
22 1926	32F	L. thigh	Clear	Single	2 mo.	Congenital lymphangioma	Recurrent lymphangitis. Excision May 22, 1926
23 1927	56F	L. thigh	Clear	Single	3 mo.	Inflammatory lymphedema	Kondoleon operation ¹⁸ , R. thigh and leg, Feb. 7, 1927
24 1929	30F	R. leg	Clear	Multiple	20 mo.	Lymphedema	Incisions for drainage performed elsewhere at monthly intervals
25 1930	18M	L. thigh	Chylous	Single	2 yr.	Diffuse lymphangioma	Struck by pedal of machine, 1929. Operation on L. inguinal region performed elsewhere May, 1930. Drainage, 1 to 2 gallons a day
26 1931	59M	Penis, scrotum	Clear	Multiple	3 yr.	Lymphedema	Bilateral dissection of inguinal nodes for gonorrhea, 1900
27 1932	53M	Anterior abdominal wall	Chylous	Single	1½ mo.	Chylous lymphangioma of the abdomen	Recurrent lymphangitis, partial excision and drainage, June 22, 1932
28	22F	R. leg	Clear	Multiple	2 mo.	Inflammatory lymphedema	Kondoleon operation ¹⁸ , Mar. 16, 1934
29 1936	27M	Scrotum	Clear	Single	3 mo.	Obstruction of abdominal lymphatics. Chylous ascites. R. inguinal hernia. Bilateral hydrocele	Excision, plastic repair of scrotum. Repair R. and L. hydrocele and R. hernia, Oct. 29, 1936
30 1937	41F	R. side of neck	Clear	Single	1 mo.	Simple lymphangioma	Excision, jugular vein ligation, Oct. 2, 1936

TABLE 2—Continued

Case and Year	Age and Sex	Fistula				Diagnosis	Trauma
		Site	Lymph	Orifices	Duration		
31 1938	50M	R thigh	Clear	Single	14 mo	Lipodystrophy	Kondoleon operation ²² , May 25, 1938
32 1938	25M	Amputation stump, L thigh	Clear	Multiple	4 mo	Fibromyxosarcoma of L thigh, inflammation of L inguinal nodes	Amputation, excision of L inguinal nodes, Oct 1, 1938
33 1939	34F	R popliteal fossa	Clear	Single	2 mo	Lymphedema	Excision, Mace operation, May 31, 1939
34 1939	96F	Thumb	Clear	Multiple	33 mo	Lymphedema	Excision, Mace operation, Nov 20, 1939 Cured by excision and skin graft with celluloid tubes Reported by Mason and Allen
35	14F	Foot	Clear	Single	1 mo	Simple lymphangioma	Excision, Aug 12, 1940
36	65F	R and L inguinal regions	Clear	Multiple	1 mo	Bilateral greater saphenous varicosities	Ligation of both greater saphenous veins, Jan 22, 1944
37	57F	Anterior abdominal wall	Chylous	Multiple	6 mo	Chylous cyst of abdomen, lymphangiectasis of wall	Fistulas developed at sites of marsupialization, right, Nov 30, 1945, left, Dec 31, 1945 Reported by Beahrs and Judd
38 1945	8 mo M	L inguinal region	Clear	Single	1 mo	Diffuse lymphangioma	Congenital Excision, lymphangioma drained, Mar 9, 1945
39 1948	43F	R and L inguinal region	Clear	Multiple	2 mo	Bilateral femoral hernias Bilateral inguinal lymphadenopathy	Bilateral femoral herniorrhaphy Bilateral inguinal node biopsy, Dec 31, 1947
40 1948	72F	L inguinal region	Clear	Single	1 mo	Melanopigmentation of L vulva, metastasis to L inguinal node	Left vulvectomy, excision of left inguinal node, Mar 18, 1948

other locations. A cure followed excision in 3 instances and a Kondoleon operation²² in 1 instance.

Traumatic Lymph Fistulas (table 2) — There were 22 of these cases. In 13 a single orifice was present

from one month to three years. The lymph was clear in 17 cases, chylous in 4 and mixed in 1. The paradoxical circulation of lymph was confirmed by the collection of chylous specimens from the parietal and peripheral

TABLE 3

THE FAT AND PROTEIN CONTENT OF 15 SPECIMENS OF HUMAN LYMPH ANALYZED AT THE CLINIC (1908 THROUGH 1918)

Specimen	Year	Diagnosis	Mode of Collection	Lymph Clarity	Total Protein, gm per 100 cc.		Total Fat, gm per 100 cc	
					Blood Serum	Lymph	Blood Serum	Lymph
1*	1920	Chylothorax	Aspirated	Chylous		4.9		1.0 to 2.0
2*	1943	Chylothorax	Aspirated	Chylous				2.055
3	1944	Chylothorax	Aspirated	Chylous	4.5	2.3	0.463	2.87
4	1945	Chylothorax	Aspirated	Chylous	3.5	1.0	0.428	1.213
5	1945	Chylothorax	Aspirated	Chylous	4.6	2.3	0.467	1.203
6	1947	Chylothorax	Aspirated	Chylous		3.7		0.448
7	1947	Chylothorax	Aspirated	Chylous	6.1	2.6	0.625	1.372
8	1933	Chylous ascites	Aspirated	Chylous		3.4		3.2
9†	1937	Chylous ascites	Aspirated	Chylous		3.8		0.878
10	1944	Chylous ascites	Aspirated	Chylous	4.6	3.0		3.155
11	1941	Chylous cyst of abdomen	Aspirated	Chylous				1.247
12‡	1946	Chylous cyst of abdomen	Free flow Marsupialization	Chylous	5.9	3.8	0.528	2.594
13	1948	Inguinal lymph fistula	Free flow	Clear		3.8		
14	1948	Inguinal lymph fistula	Free flow	Clear		4.1		
15	1930	Lower extremity lymph fistula	Free flow	Chylous			0.517	0.840 to 1.390

* Reported by Olsen and Wilson.

† Reported by Harrington and Ganshorn.

‡ Reported by Beahrs and Judd.

lymphatics in 3 cases. Of these 22 patients, 6 had lymphangioma, 7 had lymphedema and 3 had malignant neoplasms with inflammation or metastasis to the regional nodes. Chylous cyst of the abdomen, lipodystrophy, pharyngo-esophageal diverticulum, obstruction of the abdominal lymphatics, femoral hernia and greater saphenous varicosities

were the indication for the primary operation in 1 case each. The initiating trauma was surgical in 21 of the 22 cases. Lymph fistula followed excision of a lymphangioma in 5 cases, incision of a lymphangioma in 1 case, a Kondoleon operation in 4 cases, a Macey operation in 2 cases, excision of lymph nodes in 4 cases, node biopsy in 1 case, excision of a pharyngo-esophageal diverticulum in 1 case, plastic repair of the scrotum in 1 case, greater saphenous ligation in 1 case and marsupialization of a chylous cyst of the abdomen in 1 case. Traumatic lymph fistulas commonly occurred through a surgical incision and showed a tendency to close spontaneously.

Chemical Observations on Human Lymph (table 3).—Lymph from 15 patients seen at the Clinic from 1908 through 1948 was analyzed for fat and protein content. The results of these analyses support our belief that a more complete knowledge of the chemistry of human lymph would aid in the recognition of lymph fistulas. The records of these 15 patients contained information on the total fat content in 13 cases and the total protein content in 12 cases. In the 6 instances in which control studies of blood protein were done, the protein content of blood serum was appreciably greater than that of lymph, while in 5 of the 6 cases in which observations on the total fat content of blood serum and chylous lymph were made, the total fat content of lymph was two to six times that of blood serum. Nonchylous lymph was analyzed in only 2 instances.

Miscellaneous Observations.—In the course of this review, only 4 cases were found in which injury to the thoracic duct was recognized at the time of operation. In each instance the duct was lacerated but not severed in the course of block dissection of the left side of the neck (3 for metastatic malignant lesions and 1 for tuberculous nodes). Through lateral ties the openings were closed without obstructing the thoracic duct. In no instance did a lymph fistula develop.

CONCLUSIONS

The case records of 40 patients with fistulas that discharged clear and chylous lymph, encountered at the Clinic from 1908 through 1948, support the following observations on lymph fistulas:

1. The incidence of this complication is greater than the small size of this series would lead one to believe. Fistulas of clear peripheral lymph from the cervical, axillary and inguinal lymphatics have seldom been recognized and have frequently passed as "serous drainage."
2. These fistulas are always annoying and occasionally disabling.
3. Classified as to clinical onset, they may be spontaneous or traumatic.
4. Lymph fistulas are usually associated with advanced

lymphatic disease and clinically demonstrable lymph stasis. The lymph exudes from multiple orifices to give a weeping surface. Recurrent lymphangitis often is noted. The underlying lymphatic disease tends to spread, and spontaneous closure of the fistula is unusual. Surgical measures directed at the underlying lymphatic disease are occasionally of value.

5. Traumatic lymph fistulas often follow surgical procedures for the relief of stasis. However, they also occur after surgical procedures in the vicinity of large lymphatic trunks (neck, axilla and inguinal region). These fistulas are most frequently single and occur in the line of incision, usually at a drainage site. They close spontaneously in most instances.

6. Spontaneous lymph fistulas are usually longer in duration and more refractory to treatment than are traumatic lymph fistulas. Both types are commonly located below the diaphragm.

7. Clear lymph may be identified by a protein content that is lower than that of serum. In addition, the fat content of chylous lymph exceeds that of blood serum.

8. It seems that prophylaxis is the best treatment.

9. When lymphatic injury is recognized, repair or ligation of the duct and avoidance of drains appears to be the method of choice.

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OPEN-FLAP AMPUTATION

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Amputation is as old as surgery. The practice of amputation probably arose thousands of years before the birth of Christ, but no record was made of it until the Babylonian era. Many modifications and improvements in the technic of amputation have been made since that time. Prior to the sixteenth century, the cautery was the only means of preventing bleeding. In the sixteenth century, Paré introduced the ligature for tying off major vessels. The use of the tourniquet was introduced in the seventeenth century, but it was not until the nineteenth century that anesthesia was introduced.³

Although the cautery, ligature, tourniquet and anesthesia have done much to lower the mortality of amputations, sepsis of the wound has continued to be a major factor in the operative risk. In the earliest amputations, no attempt was made to close the wound, because sepsis was inevitable. By allowing the wound to heal by second intention, many lives were saved. Even following the introduction of asepsis by Lister, sepsis continued to play an important role in the risk of an amputation. The discovery and use of the sulfonamide drugs, penicillin, streptomycin and other antibiotics also have failed to prevent sepsis of the amputation stump in many cases. It is our feeling that the open-flap amputation is an adjunct in the armamentarium of any surgeon who performs amputations in cases in which infection is inevitable. We claim no originality in performing this type of amputation. Its use has been advocated by several authors^{3, 5, 6, 8} and it has advantages in certain cases.

Closed amputation, that is, amputation in which the wound is closed immediately, may be successful in carefully selected cases; however, failure is attended by such serious consequences that this type of amputation is contraindicated in cases in which infection is almost inevitable. It is likely to result in cellulitis, osteomyelitis, or gas gangrene, which will endanger the patient's life or result in the loss of an additional portion of the extremity. Langdale-Kelham and Perkins said: "The closed type of amputation should only be done: (a) after severe trauma, before infection has had time to spread up the limb (the usual limit is six hours from the accident); (b) after sepsis has completely disappeared; and (c) where there has not been any sepsis." In 1943, Bickel and Ghormley reported 103 cases of occlusive arterial disease in which a total of 110 closed amputations were performed below the knee. The results of the amputations were satisfactory in a large percentage of the cases in which the involved portion of the extremity was not grossly infected.

Although the flapless or guillotine amputation^{6, 7} has been used for centuries, it was not used extensively until World War I. Although this type of amputation has proved effective in controlling sepsis and has doubtless saved many lives, it has many disadvantages. Some of these disadvantages are as follows: (1) The wounds heal slowly; (2) an excessive amount of scar tissue forms at the distal end of the stump; (3) reamputation usually is necessary before a prosthesis can be fitted; (4)

TABLE 1

INDICATIONS FOR OPEN-FLAP AMPUTATION

- I Traumatic wounds.
 - A Extensive wounds of extremities which are more than six hours old and have severed an artery
 - B Gas gangrene of an extremity.
- II Obliterative diseases of arteries
 - A Arteriosclerosis obliterans
 - 1. Extensive infection of a foot, with or without gangrene
 - 2 Acute, fulminating ascending infection.
 - 3. Septicemia secondary to infection of a foot
 - 4 Gangrene of 1 or more toes associated with absence of pulsation in the dorsalis pedis artery
 - 5 Lymphangitis secondary to localized ulceration or gangrene in a pulseless foot
 - 6 Prolonged chronic infection of an extremity.
 - B Thromboangitis obliterans
The indications are the same as they are in arteriosclerosis obliterans
- III Miscellaneous conditions
 - A Ulcerating malignant tumors
 - B Chronic infection of a useless extremity.
 - 1 Extensive osteomyelitis in an extremity in which a nerve has been damaged irreparably
 - 2 Decubitus ulcers and cellulitis of the foot of a paraplegic patient.
 - 3 Overwhelming cellulitis or lymphangitis of a congenitally malformed extremity.
 - C Overwhelming infection of an extremity of a diabetic patient
 - D Severe third-degree burns, or gangrene resulting from exposure to cold

some type of skin traction is necessary, and this can be maintained only with much effort on the part of the surgeon and the patient, and (5) the postoperative pain and discomfort are much greater than they are after a closed amputation has been performed. The indications for open amputation are listed in table 1.

TECHNIC OF OPEN-FLAP AMPUTATION

The surgeon first should decide where he is going to divide the bone. It is a good plan to measure the length decided upon with a steel ruler,

and to mark the skin by scratching it with a needle. Planning the skin flaps is the most important part of the operation. This should be done after careful deliberation, for much of the patient's future comfort depends on the production of a scar which is linear, which does not contain any folds, which is so situated that it will not be subjected to pressure, and which is freely movable.⁵ The skin flaps should just meet, and they will do so if their combined length equals the diameter of the limb. The skin flaps are cut so that they will be of equal length, since a terminal scar is not objectionable as most artificial limbs do not exert pressure on the end of the stump.

The muscles and fascia are divided half the diameter of the limb proximal to the distal ends of the skin flaps. The large vessels are located and doubly ligated with no. 0 braided silk. Shortening of the main nerves helps to prevent them from becoming adherent to scar tissue and to the skin. They should not, however, be subjected to excessive traction. It is advisable to approach the nerves by parting the muscles. The main nerves are not ligated unless they bleed. They are cut with a sharp knife; they never should be crushed with a hemostat. Alcohol should not be injected into the nerve.

The bone is sawed through at the same level at which the muscles were divided. In cases in which the amputation is performed below the knee, the fibula is severed about 1 inch (2.5 cm.) proximal to the point at which the tibia is severed, in order to prevent the 2 bones from becoming united. The tibia is beveled anteriorly. If the amputation is performed in the thigh, the periosteum is not disturbed and the femur is divided at a right angle to the shaft.

Every bleeding point must be tied. No. 000 plain catgut is used for ligating minor vessels. A roll of petrolatum gauze which has been impregnated with 5 gm. of sulfathiazole and 50,000 units of penicillin is placed transversely in the wound. The skin flaps are drawn over the roll of gauze and are held in place with a single suture (fig. 419, *a*). A modification of the Sir Robert Jones dressing (fig. 419, *b*) then is applied in the following manner. Sterile, dry gauze is placed next to the wound. This is covered in turn with abdominal pads, sheet wadding, sterile absorbent cotton, eider-down and elastic bandages. This massive dressing absorbs any secretion, prevents flexion contractures, and is comfortable for the patient. Three to five days later, the patient is returned to the operating room, and the dressings and the roll of gauze are removed with the aid of anesthesia. If there is evidence of infection, the wound is treated as an infected wound until the flaps can be closed safely. If there is no evidence of infection, the flaps are closed immediately. Only the skin and subcutaneous tissues are drawn over the bone. The subcutaneous tissues are closed with interrupted sutures of no. 00 plain catgut; the skin is closed with

CLINICAL CONSIDERATION

Eighteen of the patients were males and 6 were females (table 2). The ages of the patients ranged from 15 to 79 years, and the average age was approximately 54 years. In 11 of the 24 cases, the patients were more than 60 years of age. The occupation of the patients was not significant. Eight of the patients were farmers, 7 did sedentary work, 5 were housewives, and 4 were laborers.

The indications for the amputation, the site of the amputation, the type of anesthesia employed, the significant laboratory findings, and other clinical data are summarized in table 2. Roentgenographic examination disclosed calcification of the blood vessels of the affected extremity in 13 cases, osteoporosis in 4 cases, and malignant destruction of the tibia and fibula in 1 case.

Preoperative Treatment.—In 4 of the 24 cases, amputation was necessitated by trauma or by a complication resulting from trauma (table 2). Therapeutic doses of tetanus antitoxin and gas gangrene antitoxin were administered in 2 of the 4 cases. Gas gangrene developed in 1 of the 2 cases in which the antitoxin was administered.

In 17 of the 24 cases, amputation was performed because of arteriosclerosis obliterans or thromboangiitis obliterans (table 2). In all of these cases, the patients were treated intensively on the medical service before amputation was performed. This treatment included local and general measures to prevent the spread of infection and gangrene. An effort was made to improve the circulation of the affected extremity. Preganglionic sympathectomy was performed in 2 of the 17 cases. Amputation was not performed unless gangrene was spreading or unless infection could not be controlled by medical treatment. In these 17 cases, the period of hospitalization before amputation was performed ranged from six to forty-one days, the average being 12.5 days.

*Diabetes mellitus also was present in 6 of the 17 cases. It was controlled by regulation of the diet and by the administration of dextrose and insulin.*²

Postoperative Treatment.—The postoperative treatment was essentially the same as that which was employed before the amputation. Penicillin was administered intramuscularly in doses of 30,000 units every three hours until the temperature returned to normal and remained there for forty-eight hours. A high vitamin diet was prescribed, and sedatives and ferrous sulfate were administered. Anticoagulants were administered in some cases. If diabetes mellitus was present, the diet was controlled and adequate doses of insulin were administered. On the twelfth day after the flaps were closed, the dressing was removed and a smaller one applied.

Results.—All of the patients survived the amputation. The time re-

quired for healing ranged from seventeen to sixty-five days, the average being 33.3 days (table 2). In 3 cases (cases 11, 12 and 15), the wound did not heal by primary intention. In the first of these cases, reclosure of the flaps resulted in satisfactory healing. In the second case, healing occurred after a split-skin graft was applied to a large granulating surface. In the third case, the wound healed by granulation and left a deep scar on the stump.

In 1 case (case 1), a mediotarsal amputation (Chopart's amputation) was performed because the patient insisted on amputation at this site. The edges of the skin of the flaps became gangrenous and it was necessary to perform a second amputation about 6 inches (15.2 cm.) below the knee. In another case (case 8), a chronic ulcer developed over the distal end of the tibia and a revision of the stump was necessary. After revision of the stump, healing occurred by first intention.

At the time of closure of the flaps, cultures of the wound were made in 11 cases (cases 7, 8, 9, 10, 11, 15, 16, 18, 20, 22 and 24). In 2 of these cases (cases 7 and 8), the cultures were negative. The following micro-organisms were produced by culture in the remaining cases: *Streptococcus faecalis* in case 9, an aerobic spore-forming micro-organism in case 10, *Clostridium perfringens* in case 11, *Staphylococcus* in cases 15 and 16, *Streptococcus faecalis* and *Staphylococcus aureus* in case 18, *Escherichia coli* in case 20, *Aerobacter aerogenes*, *Pseudomonas* and *Proteus* in case 22, and *Streptococcus faecalis* and *Corynebacterium xerosis* in case 24.

In the cases in which an upper extremity was amputated, the patients were permitted to get out of bed within twenty-four to forty-eight hours after the flaps were closed. In 19 of the 21 cases in which a lower extremity was amputated at the thigh or about 6 inches (15.2 cm.) below the knee, the interval that elapsed between the closure of the flaps and the time the patients first were permitted to walk on crutches ranged from seventeen to fifty-eight days, the average being 31.5 days. In 2 of the 21 cases (cases 14 and 22), the patients did not walk on crutches prior to their dismissal. In case 14, the opposite lower extremity had been amputated previously. The patient in this case was permitted to be up in a wheel chair on the twenty-third day after closure of the flaps. In case 22, the patient had a fracture of the femur of the other leg.

In 1 case (case 16), hemorrhage occurred just before the flaps were to be closed. The bleeding was controlled satisfactorily at the second stage of the operation. In 2 cases (cases 5 and 17), delirium developed on the second day after the primary amputation but disappeared before the flaps were closed. In 1 case (case 18) a lipoid granuloma developed in the buttock at the site of injection of penicillin. The granuloma was excised, and healing occurred by second intention. Coronary occlusion developed in 1 case (case 20), but responded satisfactorily to medical treatment.

TABLE 2
CLINICAL DATA IN 24 CASES IN WHICH FLAP AMPUTATION WAS PERFORMED

Case	Age, Yrs	Sex	Occupation	Indications for Amputation	Laboratory Findings	Site of Amputation	Type of Anesthesia	Postoperative Treatment	Heal ing, days	First Waked on Closure of Flaps	Hospitalization, Days Following Closure of Flaps	Complications
1	53	M	Refrigerator engineer	Arteriosclerosis obliterans	Not significant	First, amputation at medial region, second, on about 6 inches (15.2 cm.) below knee	Spinal For Subsequent Closure	Penicillin and dicoumarol	48	48th	78	Gangrene of skin flaps after first amputation, healing by first intention after second amputation
2	61	M	Service station attendant	Arteriosclerosis obliterans	Not significant	Below knee	Spinal Intravenous*	Penicillin	55	55th	43	
3	72	M	Printer	Arteriosclerosis obliterans	Albuminuria	Below knee	Spinal Locally	Penicillin	30	30th	31	
4	73	M	Farmer	Arteriosclerosis obliterans	Albuminuria, 240 mg. of sugar per 100 cc. of blood	Below knee	Spinal	Insulin and penicillin	46	46th	50	
5	70	M	Farmer	Arteriosclerosis obliterans	54 mg. of urea per 100 cc. of blood	Thigh	Spinal Intravenous*	Penicillin and couphen	18	18th	22	Postoperative delirium
6	32	M	Farmer	Trauma	Not significant	Forearm	Intravenous*	Penicillin	19		12	

7	43	M	Welder	Thromboangitis obliterans	Not significant	Below knee	Intravenous*	Intravenous*	Penicillin	22	22nd	23	
8	71	M	Laborer	Arteriosclerosis obliterans	Not significant	Below knee	Intravenous*	Intravenous*	Penicillin	45	21st	45	Ulcer of stump
9	68	F	Chemist	Arteriosclerosis obliterans	305 mg. of sugar per 100 cc of blood; wound culture positive for Streptococcus faecalis	Below knee	Intravenous*	Intravenous*	Penicillin and insulin	19	20th	27	
10	48	M	Locomotive engineer	Thromboangitis obliterans	Wound culture positive for spore-forming micro-organisms	Below knee	Spinal	Intravenous*	Penicillin	23	23rd	23	
11	20	M	None	Gunshot wound	9.8 gm of hemoglobin per 100 cc. of blood; wound culture positive for Clostridium perfringens	Forearm	Intravenous*	Intravenous*	Penicillin	51		53	Healing by second intention
12	37	M	Truck driver	Diabetic abscess of foot	Albuminuria and glycosuria; 390 mg. of sugar per 100 cc. of blood	Below knee	Spinal	Intravenous*	Penicillin, streptomycin, and tetanus and gas gangrene antitoxin	40	46th	46	Healing by second intention

TABLE 2—Continued

Case	Age, Yrs	Sex	Occupation	Indications for Amputation	Laboratory Findings	Site of Amputation	Type of Anesthesia		Postoperative Treatment	Healing, days	First Walked on Crutches, Day after Closure of Flaps	Hospitalization, Days following Closure of Flaps	Complications
							For Amputation	For Subsequent Closure					
13	49	M	Farmer	Thrombangitis obliterans	Not Significant	Below knee	Spinal	Spinal	Insulin and penicillin	18	18th	18	
14	71	F	Housewife	Arteriosclerosis obliterans	Albuminuria, 267 mg of sugar per 100 cc of blood	Thigh	Spinal	Spinal	Insulin and penicillin	23		32	
15	59	M	Tavern keeper	Arteriosclerosis obliterans	Wound culture positive for <i>Staphylococcus</i>	Below knee	Intravenous*	Intravenous*	Sulfadiazine and penicillin	50	50th	52	Healing by second intention
16	59	F	Housewife	Arteriosclerosis obliterans	165 mg of sugar per 100 cc of blood, wound culture positive for <i>Staphylococcus</i>	Below knee	Intravenous*	Intravenous*	Sulfadiazine and penicillin	58	58th	150	Secondary hemorrhage
17	79	M	Farmer	Arteriosclerosis obliterans	Albuminuria, 78 mg of urea per 100 cc of blood	Thigh	Spinal	Intravenous*	Penicillin and dicumaryl	25	26th	40	Delirium

18	76	P	Housewife	Fibrosarcoma	Albuminuria, 52 mg of urea per 100 cc of blood, wound culture posi- tive for <i>Sty-</i> <i>lococcus</i> and <i>Staph aureus</i>	Thigh	Spinal	Intra- neous*	Penicillin	33	33rd	63	Lipoid, granu- loma of but- tock
19	53	M	Farmer	Arteriosclerosis obliterans	Albuminuria	Toe	Intra- neous*	Intra- neous*	Penicillin	65	6th	6	
20	61	F	Housewife	Arteriosclerosis obliterans	60 mg. of urea and 150 mg of sugar per 100 cc of blood, wound culture posi- tive for <i>Sty-</i> <i>lococcus</i> coli	Below knee	Spinal	Local	Insulin and penicillin	35	40th	42	Coronary occlu- sion
21	69	M	Farmer	Arteriosclerosis obliterans	Albuminuria, .214 mg. of su- gar per 100 cc of blood	Below knee	Spinal	Spinal	Insulin and penicillin	26	20th	29	
22	15	M	Student	Traumatic occlu- sion of right popliteal ar- tery	Leukocyte count 19,300 per cu mm of blood, 10.5 gm of hemo- globin per 100 cc of blood, wound cul- ture positive for <i>Aerobac-</i> <i>ter aerogenes</i> , <i>Pseudomonas</i> and <i>Proteus</i>	Below knee	Intra- neous*	Intra- neous*	Penicillin and strep- tomycin, blood trans- fusions	21		34	

TABLE 2—Continued

Case	Age, Yrs	Sex	Occupation	Indications for Amputation	Laboratory Findings	Site for Amputation	Type of Anesthesia		Postoperative Treatment	Healing, Days	First Walked on Crutches, Day after Closure of Flaps	Healing, Days Following Closure of Flaps	Complications
23	29	F	Housewife	Gangrene of left leg	Not significant	Distal third of thigh	For Amputation	For Subsequent Closure	Penicillin, sulfathiazole and whiskey	17	17th	17	
24	17	M	Farmer	Gas gangrene of right thigh following gun shot wound	9.8 gm of hemoglobin per 100 cc of blood, culture of wound positive for Streptococcus faecalis and Corynebacterium xerosis	Middle of thigh	Nitrous oxide	Intravenous*	Penicillin, sulfathiazole, gas gangrene antitoxin and many transfusions of blood, isotonic solution of sodium chloride administered intravenously	22	22nd	26	

* Pentothal sodium administered intravenously

† Infiltration with a 1 per cent solution of procaine hydrochloride

REPORT OF CASE

CASE 22.—A boy, aged 15 years, was referred to the Clinic on November 10, 1948. He was admitted to the hospital immediately. He had been thrown from a horse on October 19. His left thigh had struck a tree, and he had landed on his right knee. He had been taken to a hospital where examination had disclosed a fracture of the shaft of the left femur and a fracture of the upper part of the right tibia. Three days later, the fracture of the left femur had been reduced by open operation and a metal plate had been inserted to maintain reduction. After the wound had been closed, a single spica cast had been applied. At the same time, an exploratory operation on the right knee had disclosed that "the nerve was intact but stretched." The surgeon had told the patient that the circulation seemed to be impaired. A long cast had been applied to the right lower extremity.

Within forty-eight hours after the operation, the right toes and foot had become cyanotic. Ice bags had been applied to the foot, penicillin had been admin-



Fig. 423.—Infection and gangrene of foot resulting from traumatic occlusion of the popliteal artery (case 22).

istered, and supportive treatment, including transfusions of blood, had been employed. In spite of this therapy, the condition of the right foot had deteriorated progressively. The cast had been removed from the right lower extremity. Fever had occurred daily, and he occasionally had had a chill.

When the patient was admitted to the hospital in Rochester, he was still encased in a single spica cast which extended to the ankle on the left side. He complained of pain and loss of function in his right foot. His temperature was 100.4° F.

rior instability of the right knee. The leukocyte count was 19,300 per cubic millimeter of blood, and the value for the hemoglobin was 10.5 gm. per 100 cc. of blood. The urine was normal. A flocculation test did not disclose any evidence of syphilis. A roentgenogram of the thorax was normal. Roentgenographic examination revealed a fracture of the middle third of the shaft of the left femur. The fragments were being held in satisfactory apposition by the metal plate which had been applied previously. Roentgenographic examination also disclosed a

fracture of the plateau of the right tibia. One of the fragments was displaced posteriorly; the other, laterally.

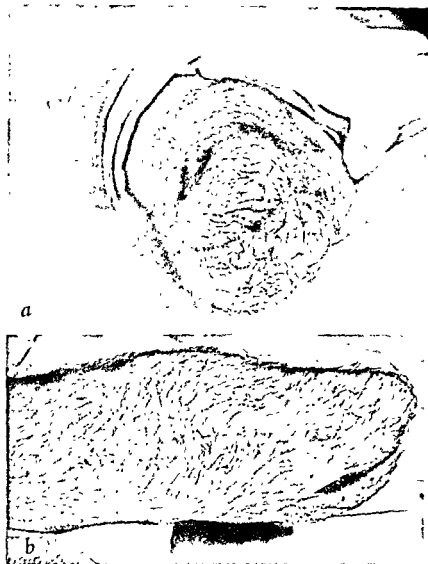


Fig 421.—Appearance of stump approximately eighteen weeks after amputation (case 22) *a*, Infero-anterior view. *b*, Lateral view. The longitudinal scar, which was 17 inches (43.2 cm.) long, was the result of an exploratory operation which had been performed previously.

The subsequent course of the patient's illness was stormy. He had a septic type of fever. The swelling of the right foot and leg increased, and considerable sloughing occurred in the dorsum of the right foot. This produced a moderate amount of purulent exudate which had a foul odor.

On November 18, 1948, an open-flap operation was performed below the right knee. The peroneal muscles were markedly necrotic, and purulent material exuded from the amputation stump. A large roll of petrolatum gauze containing 5 gm. of sulfathiazole and 50,000 units of penicillin was placed in the wound and anchored with a silk suture which was passed through the skin. A modified Sir Robert Jones pressure dressing was applied. Cultures of the wound were positive for *Aerobacter aerogenes*, *Pseudomonas* and *Proteus*. The patient's temperature and pulse rate became normal, and his general condition improved. Six days after the amputation was performed, the flaps were closed loosely with silk sutures which were passed through the skin. The postoperative treatment consisted of the administration of penicillin and streptomycin and repeated transfusions of blood. The original spica cast was removed from the left leg and a similar cast was applied so as to include the foot. Since the operative wound in the left thigh became infected, it was necessary to make a window in the cast over the thigh.

The healing of the amputation stump was complete in twenty-one days after the flaps were closed. The patient was dismissed to the care of his family physician forty-two days after he was admitted to the hospital. When the patient returned to the Clinic for a check-up four months after his dismissal, examination revealed that his physical condition was satisfactory. Figure 421, *a* and *b* shows the appearance of the stump at the time the patient returned to the Clinic.

SUMMARY

This report is based on a review of 24 cases in which open-flap amputation was performed at the Clinic in 1948. There were no deaths in this group of cases.

Open-flap amputation has all of the advantages of a flapless or guillotine amputation and has fewer disadvantages. It is of particular value in cases in which the involved extremity is infected and the operative risk is poor. Although it is commonly believed that amputation below the knee is contraindicated in cases of diabetic gangrene of the foot, we have performed an open-flap amputation at this site in 6 cases of diabetic gangrene of the foot and the results have been satisfactory in all of the cases.

Some surgeons may hesitate to perform this type of amputation because the patient has to be anesthetized twice; first, for the primary amputation; second, for subsequent closure of the flaps. In 2 of the 24 cases in our series, local anesthesia was used for closure of the flaps. The anesthesia was satisfactory in both of these cases.

The time required for primary amputation by the open-flap method is much shorter than that required for amputation by the closed-flap method. This may partially explain the lower mortality rate associated with open-flap amputation.

Although the time required for healing may be longer than it is after amputation by the closed-flap method, it should be remembered that

open-flap amputation chiefly is indicated in cases in which the involved extremity is infected and the operative risk is poor.

CONCLUSIONS

1 Open-flap amputation frequently is a lifesaving measure in cases in which an extremity is infected and the operative risk is poor.

2. In many cases, the use of this type of amputation will permit the surgeon to perform a conservative primary amputation without increasing the operative risk unduly.

3. Although the guillotine or flapless amputation frequently is a life-saving measure, it has several disadvantages which make it less desirable than the open-flap amputation

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CLINICS ON OTHER SUBJECTS

JAUNDICE IN GENERAL SURGERY: LABORATORY DIAGNOSTIC AIDS

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A surgeon, when presented with a case of jaundice, wishes to know one thing: Is this a type of jaundice which can be relieved by surgical means? To make this decision, he must determine whether the jaundice is hemolytic, hepatocellular or obstructive in origin. In making the diagnosis the value of a complete and careful history and physical examination cannot be overemphasized, but also of great aid, and often the only means of confirming the diagnosis of the type of jaundice, are the laboratory tests of liver function.

Surgeons many times are prone to disregard the advantages of liver function tests which are available to them for aid in the diagnosis of jaundice. This disregard stems in general from two causes: first, the surgeon may have encountered cases in which the liver function tests were inconclusive or misleading in their results, and second, but perhaps the more important, he does not have faith in the tests because he does not understand clearly the principles involved nor the real purposes for which each test was developed. It is a common experience that one tends to be suspicious of something about which one is unfamiliar. Because of these reactions, this paper will attempt to describe simply and clearly, for the surgeon, some of the more commonly used tests of liver function as aids in diagnosis. There have been developed many minor variations in the technic of performing these tests, and the details of their interpretations vary from laboratory to laboratory; these variations of thought and technic are beyond the scope and intent of this paper.

To our knowledge, there is no laboratory procedure which will test all the functions of the liver at one time. It is easy to see why this is so when one realizes that the liver is probably the most important single organ in maintaining the various factors of homeostasis within the body. It accomplishes this not only by its influence on the metabolism of carbohydrates, lipids, proteins, vitamins and bile, but also through many other functions too numerous and nebulous to mention. Because of this great diversity of activity, a liver function test is designed to test only one specific function of the liver, and its interpretation is of this specific activity and secondarily of its relationship to the other functions of the liver.

Any condition of the liver which will produce pathologic changes in

TABLE 1
RESULTS OF LABORATORY TESTS IN VARIOUS TYPES OF JAUNDICE

Procedure or Feature	Normal	Jaundice, Type			
		Hepatogenous	Obstructive, Stone	Obstructive, Carcinoma	Hemolytic
Degree of jaundice	None	Variable	Variable	Deep and persistent	Variable
Evidence of hepatic functional disturbance	None	Early	Later and progressive	Later and progressive	None
Icterus index	4-6 units	Elevated	Elevated	Elevated	Elevated
Serum bilirubin (van den Bergh)	Negative direct, 0.6 mg per 100 cc indirect	Increased direct and indirect reaction	Increased direct reaction	Markedly increased direct reaction	Increased indirect reaction
Urobilinogen	Present in stool and urine	Present in stool and urine	Present or decreased in stool and urine	Absent in stool and urine	Increased in stool and urine
Duodenal drainage, bile	Present	Present	Present or decreased	Absent	Present
Glucose tolerance	Normal curve	Increased response	Normal curve	Normal curve	Normal curve
Galactose tolerance	Less than 3 gm in 5 hours	Reduced over 3 gm	Normal (early)	Normal (early)	Normal
Albumin globulin ratio	1.5:1 to 2.5:1	Reduced or inverted	Normal (early)	Normal (early)	Normal
Takat-Ara	Negative	Positive	Negative	Negative	Negative
Cephalin-cholesterol flocculation	No flocculation	Increased, grade 3 to 4	Normal (increased late)	Normal (increased late)	Normal
Colloidal gold precipitation	Negative	Paretic type of curve	Negative	Negative	Negative
Thymol turbidity	0-4 units	Positive	Negative	Negative	Negative
Prothrombin time	15-20 seconds	Prolonged, poor response to vitamin K	Prolonged, good response to vitamin K	Prolonged, good response to vitamin K	Normal
Cholesterol, total	150-250 mg per 100 cc	Normal or decreased	Increased	Increased	Normal
Cholesterol esters	110-145 mg per 100 cc	Reduced	Increased	Increased	Normal
Dye retention	None	Increased	Increased	Increased	None
Hippuric acid excretion	3 gm or more in 4 hours	Reduced, 2 gm or less	Normal (early)	Normal (early)	Normal

TABLE 1 (Continued)

Procedure or Feature	Normal	Jaundice, Type			
		Hepatogenous	Obstructive, Stone	Obstructive, Carcinoma	Hemolytic
Serum alkaline phosphatase	5 units or less per 100 cc.	Moderately elevated	Increased	Increased	Normal
Serum amylase	Less than 320 units	Normal	Increased	Increased	Normal
Serum lipase	Less than 0.3 cc.	Normal	Increased	Increased	Normal

one function of the liver will ultimately cause enough damage to the parenchyma of the liver to produce changes in other functions. The average length of time for this secondary damage to become manifest is from two to four weeks. Hence liver function tests are of greatest aid in the diagnosis of jaundice during the initial two weeks of the disease. After this time has elapsed, all the tests tend to give positive results to a varying degree, and hence the specificity of the various tests is lost as is their diagnostic value. For this reason, liver function tests for the diagnosis of jaundice should be performed as early in the course of the disease as possible.

A summary of the results of the different laboratory tests in various types of jaundice is given in table 1.

TESTS OF BILE EXCRETION

Perhaps the most frequently performed tests of liver function are those which determine the ability of the liver to excrete bile pigments which, when they are present in excess in the blood, produce the clinical manifestation of jaundice. Tests of this function of the liver are the icterus index, determinations of serum bilirubin (van den Bergh), determination of fecal and urinary urobilinogen, and duodenal drainage.

Icterus Index.—The icterus index is a colorimetric test in which the color of the fasting xanthophyll-free and carotin-free serum which contains no hemolyzed erythrocytes is compared with a standard potassium dichromate solution. The results of the test are not directly proportional to the amount of bile present in the serum since the bilirubin present in crystalloid form gives a deeper color than does colloidal bilirubin; hence the results do not always agree with those of the van den Bergh test. The results are reported in units, each of which is roughly equivalent to 0.05 mg. of bilirubin per 100 cc. of serum. The normal icterus index is 4 to 6 units, but it may increase to 15 units before gross evidence of clinical jaundice appears. This test is a nonspecific test for jaundice, and it is increased in any condition which produces jaundice. Its main use

is in following the variations in the degree of jaundice in a patient, since it is an easy simple test.

Quantitative Determination of Serum Bilirubin (van den Bergh Test).—The quantitative serum bilirubin (van den Bergh) test is a colorimetric procedure which is much more specific than the icterus index. It is perhaps the most frequently used test in the diagnosis of jaundice. The bile present in the serum reacts with Ehrlich's diazo reagent (diazotized sulfanilic acid) to produce a reddish color. The time that it takes the color to develop and the depth of the color determine the type of the reaction and the amount of serum bilirubin. If the color develops within sixty seconds, the result is known as a "direct reaction." This indicates that the bilirubin is in a more soluble form as a result of having passed through, and having been excreted by, the liver cells. If the color develops in from sixty seconds to several hours, it is known as a "delayed reaction." This may be considered as a negative direct reaction. In the second phase of this test, a solution of 50 per cent methyl alcohol is mixed with the serum and Ehrlich's reagent is added. This frees the protein-bound bilirubin which has not passed through the liver cells so it can react with Ehrlich's reagent to produce the reddish color. This is known as the "indirect reaction." Normal persons usually give a negative direct reaction for serum bilirubin, and an indirect reaction for serum bilirubin up to values of 0.6 mg. per 100 cc. In the obstructive type of jaundice it is mainly the direct-reacting bilirubin which is present, but if the obstruction persists, there will soon be varying degrees of damage to the liver cells so that there will also be an increase in the indirect-reacting serum bilirubin. The bilirubin in hemolytic jaundice produces an entirely indirect reaction, as it has not passed through the liver cells. In hepatocellular jaundice the bilirubin in the early stages is mainly indirect reacting, but as the disease progresses, it becomes both direct and indirect reacting.

Test for Urobilinogen.—Urobilinogen is formed in the intestine by the action of the intestinal bacteria on bilirubin. The majority of the urobilinogen is excreted in the feces as urobilin, stercobilin and mesobiliviolin. A small portion of the urobilinogen is resorbed into the portal circulation from the intestine and it passes back to the liver where most of it is again excreted into the intestine (enterohepatic circulation). However, a small portion of it passes into the general circulation from which it is excreted by the kidney in the urine.

The test for urobilinogen, whether in the urine or the feces, again depends on the reddish color produced by bilirubin or its derivatives and Ehrlich's reagent (paradimethylaminobenzaldehyde). This color is compared with that of a standard solution. The urobilinogen in the feces is reported as milligrams per 100 gm. of stool or milligrams excreted per

twenty-four hours. The normal amounts are 150 to 300 mg. per 100 gm. of feces or a daily output of 40 to 300 mg. of urobilinogen. The amount is decreased or absent in obstructive jaundice, and it tends to be much lower, if not entirely absent, in obstructive jaundice due to neoplasm than in that due to stone. The amount of fecal urobilinogen is increased in hemolytic jaundice.

In the urine, the normal amount of urobilinogen is 4 mg. or less per twenty-four hours. It is absent in case of complete biliary obstruction, and it is increased in case of hepatocellular damage or hemolytic jaundice.

Duodenal Drainage.—Duodenal drainage is a valuable procedure. A Levine type of tube is passed so that the tip will rest in the duodenum. Fifty cubic centimeters of a 25 per cent solution of magnesium sulfate is instilled through the tube. Normally, the first bile is clear and thin as it comes from the common duct. This is followed by a much thicker and darker bile which apparently is from the gallbladder. The last bile to be obtained is again clear and thin and is considered to be that which has just been excreted by the liver. The bile, if obtained, indicates at least some degree of patency of the bile ducts, but it may be minimal in amount in cases of severe hepatocellular damage. The presence of cholesterol and calcium bilirubinate crystals is indicative of stones in the biliary system, and blood is indicative of tumor although it may result from trauma. Pus cells are found in cases of cholangitis, and the recognition of malignant cells in bile may be of practical value at some future time.

TESTS OF CARBOHYDRATE METABOLISM

Glucose Tolerance Test.—The glucose in the blood is maintained, in part, at near constant levels by the liver which converts glucose to glycogen, in which form it stores carbohydrates until the extrahepatic stores of glucose are decreased. Glycogen is then reconverted to glucose and is released into the general circulation.

The glucose content of the blood is determined by heating protein-free blood filtrate with an alkaline copper solution. The glucose reduces a portion of the copper to cuprous oxide which in turn reduces phosphomolybdic acid to phosphomolybdous acid which is blue in color. This color is compared with a standard, and the amount of glucose reported in milligrams per 100 cc. The glucose tolerance test is performed, after determining the fasting level of glucose in the blood, by giving the subject orally an amount of glucose calculated on the basis of body weight. The levels of glucose in the blood and urine are then determined at intervals of thirty minutes, one, two and three hours.

When there is damage to the liver cells, wide variations are noted in the levels of glucose in the blood in response to the glucose tolerance

test. Following the administration of glucose, the level of this substance rises rapidly in the blood, but the curve differs from that of the diabetic in that it falls more quickly to fasting levels. The fasting level in the nondiabetic patient with hepatocellular disease is reached in two to three hours. The results of the glucose tolerance test may be indicative of hepatocellular disease, but owing to its nonspecific nature, it is not often used for the diagnosis of this type of jaundice.

Galactose Tolerance Test.—Much more specific for the diagnosis of jaundice is the galactose tolerance test. Galactose is a carbohydrate which is converted to glycogen entirely by the liver and it is not metabolized as galactose by the extrahepatic metabolic processes of the body. The test is commonly done by giving the fasting patient 40 gm of galactose in 400 cc. of water by mouth. The amount of galactose excreted in the urine, that is, not metabolized by the liver, is measured over a five-hour period. More delicate is the intravenous galactose tolerance test wherein 1 cc. of a 40 per cent solution of galactose is given per kilogram of body weight. The quantity of galactose in the blood is determined after seventy-five minutes.

With the use of the oral-urinary method of determining galactose tolerance, the normal person excretes 3 gm. or less of this sugar in five hours. In the hepatocellular type of jaundice, 4 or 5 gm. are excreted. In an obstructive type of jaundice, 40 to 50 per cent of the patients will give positive results with the galactose tolerance test, which means that quantities in excess of 3 gm. are excreted in a five-hour period. In general the test is not a definite diagnostic test, but the results may corroborate other evidence to help make the diagnosis. The intravenous test is much more sensitive. It has been reported that when more than 20 mg. of galactose per 100 cc. remained in the blood after seventy-five minutes, the results of the test were positive in 97 per cent of the cases of cirrhosis, in 81 per cent of the cases of hepatitis, and in 18 per cent of the cases of obstructive jaundice of less than six months' duration.

TESTS OF PROTEIN METABOLISM

In the synthesis of body proteins, the liver serves as an important link. The amount of total serum proteins reflects this function in that it is moderately decreased in chronic hepatocellular disease. However, the amount of total serum proteins is affected by many conditions other than disease of the liver, and hence it is of no great diagnostic significance.

Albumin-Globulin Ratio.—Of more importance in the diagnosis of jaundice is the albumin-globulin ratio and the changes which occur in the globulin fraction of the serum proteins. In primary hepatocellular disease there is a decrease in the albumin fraction and an increase in the globulin

fraction of the serum proteins, thus producing a lowering or inversion of the normal albumin-globulin ratio of 1.5:1 to 2.5:1.

Tests for Abnormal Serum Globulin.—When damage to the parenchyma of the liver has occurred, more specific changes are seen in the gamma globulin fraction of the serum proteins than in the albumin fraction. These changes are not due primarily to changes in the liver but they seem to be the result of reticulo-endothelial irritation. Hepatitis can produce these changes but other conditions producing reticulo-endothelial irritation such as subacute bacterial endocarditis, rheumatoid arthritis, infectious mononucleosis, and tuberculosis can also produce the same changes in the serum globulin and hence also give the same reactions. However, it is usually not necessary to consider these diseases when one is trying to classify a type of jaundice. Tests which utilize changes in the globulin fraction of the serum proteins are the Takata-Ara test, cephalin-cholesterol flocculation test, colloidal gold flocculation test, and the thymol turbidity test.

Takata-Ara Test.—The oldest of this group is the Takata-Ara test. In this test mercuric chloride and sodium carbonate react with the abnormal globulin in blood to precipitate mercuric oxide. In general, the test is difficult to perform and difficult to interpret. Positive reactions are obtained in late cirrhosis and other forms of hepatocellular disease. Negative reactions are found in obstructive jaundice and metastatic malignant disease of the liver. Because this test is not highly sensitive in relation to hepatic function and because a large variety of conditions not related to disease of the liver give positive reactions, it is little used today.

Cephalin-Cholesterol Flocculation Test.—This test is a useful one introduced by Hanger in 1939. It depends on the production of a precipitate (flocculation) of a prepared cephalin-cholesterol mixture by the abnormal globulin of the patient's serum. The reaction, as in other flocculation tests, depends on the presence of excessive amounts of gamma globulin and a decrease in the albumin or fraction of the albumin which inhibits the flocculation. The test is read after forty-eight hours and is reported on the basis of grades 1 and 4, depending on the degree of flocculation. Grade 3 and grade 4 reactions are considered significantly positive. The test is of great aid in the diagnosis of infectious hepatitis as the result is almost always strongly positive even in the early stages of the disease. The result is also positive in a high percentage of cases of cirrhosis or advanced metastatic involvement of the liver with cancer. It is usually negative in obstructive jaundice until the obstruction produces secondary changes in the liver.

Colloidal Gold Precipitation Test.—The colloidal gold precipitation test of Lange on spinal fluid has been modified for use with blood serum.

The test depends on the precipitation of the colloidal gold by the abnormal globulin in the serum with the resulting decolorization of the solution. Complete decolorization of the solution is indicated by the figure "5." Varying dilutions of serum are used, and a positive reaction produces a curve similar to the paretic curve of the spinal fluid (5555542100). Like other flocculation reactions it is positive in hepatocellular disease.

Thymol Turbidity Test—The thymol turbidity test was introduced by Maclagan in 1944. It has proved to be extremely useful because it is easy to perform and because it is one of the most reliable tests in the differentiation of obstructive jaundice from hepatocellular jaundice. A positive reaction depends on the abnormal globulin of the blood, producing flocculation of a saturated thymol solution of pH 7.8 which contains a barbitone buffer. The turbidity of the solution is compared with Kingsbury turbidity standards, and the results are reported in units of turbidity. The normal turbidity is from 0 to 4 units. Positive reactions early in the course of jaundice indicate hepatocellular damage, and negative reactions in early jaundice indicate that obstruction is the cause. In general, it has been shown that the thymol turbidity test gives more uniformly negative results in the obstructive type of jaundice while the cephalin-cholesterol flocculation test is more likely to give positive results in hepatocellular disease.

Prothrombin Time.—Prothrombin is a carbohydrate-containing protein produced exclusively by the liver when adequate amounts of vitamin K are present. Vitamin K is a fat-soluble vitamin which is absorbed from the intestine in significant amounts only when bile is present. Hence prothrombin may be deficient either when there is severe hepatocellular damage or when there is obstruction to the bile passages.

The amount of prothrombin in the blood is measured indirectly by its ability to produce a clot in a definite period of time. Standard conditions are set up using the patient's plasma, an excess of calcium and a prepared solution of thromboplastin. The time that it takes the mixture to produce a clot is known as the prothrombin time, and it is very roughly inversely proportional to the amount of prothrombin present. The normal prothrombin time varies with the type of thromboplastin used so that controls must be run frequently, normal times are usually in the range of 18 to 20 seconds.

In jaundice, in which the prothrombin time is elevated, it is important to know if the prothrombin time will return to normal when adequate amounts of vitamin K are given parenterally; little change in the prolonged prothrombin time indicates severe hepatocellular damage, but rapid return to normal after administration of vitamin K indicates that

the jaundice is most likely on an obstructive basis or that there is little or no damage to the liver cells.

TESTS OF LIPID METABOLISM

Determination of Cholesterol and Cholesterol Esters.—Cholesterol is a sterol found in all body tissues and fluids. The liver cells have the ability to esterify free cholesterol, and thus cholesterol esters are found to make up 70 to 76 per cent of the total cholesterol in persons with normal liver function.

Total cholesterol is determined by first extracting it from the plasma with alcohol, ether and chloroform. Acetic anhydride and sulfuric acid are then added, and a green color is produced. This is compared with the color of a standard solution. Cholesterol esters are determined by precipitating the free cholesterol with digitonin and then extracting the esters with petroleum ether. The amount of esters is then determined by the above-described color reaction. The normal value for total cholesterol is from 150 to 250 mg. per 100 cc. of plasma.

The value for blood cholesterol varies in a great many conditions. In obstructive jaundice there is a rise in the value for total cholesterol and also in the esters, so that there is little or no change in the ratio. Hepatocellular jaundice causes no change or a slight decrease in the content of total cholesterol, but there is a marked decrease in the amount of cholesterol esters present so that their percentage of the total is markedly decreased. This decrease is roughly proportional to the severity of the damage to the liver.

TESTS OF EXCRETION OF DYE

It has been found that a number of dyes are removed from the circulation and excreted by the liver. Two of these which are used clinically to evaluate the status of the liver are sulfobromophthalein sodium (brom-sulfalein) and rose bengal. These dyes are rapidly removed from the circulation by the reticulo-endothelial system (Kupffer cells in the liver) and then are more slowly excreted in the bile after having passed through the hepatic cells.

In the sulfobromophthalein test 5 mg. of the dye per kilogram of body weight are injected intravenously and a reading is made of the amount of dye remaining in the serum after sixty minutes; normally there is no dye remaining in the serum at that time. Rose bengal is given intravenously in a dose of 10 cc. of 1 per cent solution. The amounts remaining in the serum are determined in two and six minutes respectively. In a normal person 50 per cent of the dye present in the two-

minute sample will have been removed by the time six minutes have elapsed

Dye excretion tests best indicate the status of the liver in cases in which there is little or no jaundice. Whether jaundice is due to hepatocellular disease or obstruction to the bile ducts, there will be marked retention of dye so that as a test to differentiate these two types of jaundice, this type of procedure is of little value

DETOXIFICATION TESTS

Hippuric Acid Test.—The liver acts to protect the body from certain toxic substances by causing conjugation to form relatively nontoxic substances which are excreted in the bile and urine. Some of these toxic substances are indol, salicylic acid and menthol. Benzoic acid has been used as a test of this function since it is conjugated with glycine, which is produced only by the liver, and is formed into hippuric acid in the liver and kidneys and is excreted as such in the urine.

The accuracy of this test depends on the ability of the kidney to excrete the hippuric acid, hence it is not recommended for patients who have an elevated value for nonprotein nitrogen. It also depends on an adequate output of urine and a complete emptying of the bladder. The benzoic acid can be given orally or intravenously but the intravenous method is the more sensitive. The oral test is done by giving the subject 6 gm. of sodium benzoate, and the urine is collected for the following four-hour period. With the intravenous method, 1.77 gm. of sodium benzoate is given, and the urine is collected for one hour. The hippuric acid is precipitated from the urine with ammonium sulfate and hydrochloric acid and is weighed. In the intravenous test, 0.7 to 1.2 gm. are excreted in an hour while with the oral test 3 to 4 gm. are excreted in four hours by the normal person.

Obstructive jaundice of short duration and hemolytic jaundice are associated with normal levels of excretion whereas all types of hepatocellular jaundice are associated with a marked decrease in the amount of hippuric acid excreted

SERUM ALKALINE PHOSPHATASE TEST

Alkaline phosphatase, an enzyme, is produced in the body mainly by the osteoblasts and is excreted to a large extent by the liver. When abnormal osteoblastic activity is not present, elevation of the value for serum alkaline phosphatase is usually due to damage of the liver. The amount of alkaline phosphatase in the serum is determined by incubation of the serum with a glycerophosphate solution to produce inorganic phosphate (Bodansky method). The results are expressed in Bodansky units; 1 Bodansky unit is equivalent to 1 mg. of phosphorus liberated.

Normal adults have 1.5 to 5 units of serum alkaline phosphatase per 100 cc. of serum.

In general, the test is not one of great diagnostic value in the differential diagnosis of jaundice. Elevations in the value for alkaline phosphatase do not parallel the degree of hepatocellular damage. The amount is usually normal in hemolytic jaundice, moderately increased in hepatocellular jaundice, and markedly increased in obstructive jaundice, but the increases are not constant enough to be of great diagnostic significance.

TESTS OF SERUM AMYLASE AND LIPASE

Amylase is found in the serum in remarkably constant amounts, and the amount is unaffected by food, starvation, diuresis or dehydration. The source has not been proved but it is suspected that amylase is produced mainly by the pancreas and the salivary glands. Obstruction of the pancreatic duct due to ligation or inflammation produces a pronounced elevation of the serum amylase levels, and similar elevations are found in acute epidemic parotitis. Sudden obstruction of the common bile duct or pancreatic duct will cause a decided increase but the effect is transient and normal levels are regained in seventy-two hours.

The serum amylase is determined on the basis of the length of time required for the amylase to digest a standard starch solution. The degree of digestion is determined by noting the change in color of a mixture of iodine and starch from blue to brown when the starch is all digested. The results are calculated by formula and are reported in units of amylase activity. The normal is 80 to 150 units, and to be clinically significant the value must be over 320 units. In the icteric patient, elevations are most commonly seen when the jaundice is obstructive in nature. The levels are usually normal in hemolytic and hepatocellular jaundice.

Like that for serum amylase, the value for serum lipase is elevated in the obstructive type of jaundice. The level of lipase activity is measured by the effect of the serum lipase on an olive oil emulsion to produce free fatty acids which are measured by titration with tenth-normal solution of sodium hydroxide. The results are reported in cubic centimeters of sodium hydroxide solution needed to neutralize the fatty acids produced by 1 cc. of serum. The normal is less than 0.3 cc. of tenth-normal solution of sodium hydroxide per cubic centimeter of serum, but the amount may rise as high as 10 cc. in cases of acute pancreatitis.

COMMENT

As a surgeon reviews the problem of diagnosis of the jaundiced patient, he is struck by the great value of a careful and complete physical exam-

ination and history. In many cases the diagnosis can be made by these means alone. However, in spite of the certainty with which one can make the diagnosis in many cases, routine liver function tests should be performed to confirm the diagnosis even when the clinical picture seems to make the etiology of the jaundice obvious. This may seem superfluous at times, but if the tests are done, some cases in which the clinical picture is entirely misleading will be uncovered and the correct diagnosis will be made, which may save the patient an unnecessary operation. In many cases the clinical picture will be inconclusive. In these cases the liver function tests are not used to support the diagnosis but are depended upon to establish the diagnosis. This they will do in most instances. In such cases the tests have proved invaluable. Finally in a few cases the laboratory tests as well as the history and physical examination will prove inconclusive. It is in these cases that surgical judgement and experience are invaluable, for surgical treatment may cause cure when correctly applied or injury to the patient when ill advised. Unfortunately, surgical judgment cannot be acquired from the printed page or in the laboratory. It is best developed by experience and, in particular, careful analysis of one's past errors.

SUMMARY

It has been pointed out that liver function tests, in addition to a complete history and physical examination, are of great importance in determining the etiologic factors which cause jaundice. To be of greatest aid, these tests should be performed as early in the course of jaundice as possible. The essential laboratory procedures which should be used for diagnosis in all cases of jaundice pertain to determination of the serum bilirubin, urinary urobilinogen, duodenal drainage, cephalin-cholesterol flocculation, thymol turbidity and prothrombin time. The essential principles and procedures of these tests and other tests have been presented so that they may be better understood by the general surgeon, and the results of these tests in the various types of jaundice have been presented in tabular form.

THE INDICATIONS FOR SURGICAL TREATMENT IN MÉNIÈRE'S DISEASE

HENRY L. WILLIAMS

Before the indications for surgical treatment in an individual case of Ménière's disease are considered, two very important decisions must be made. The first is what is meant by the term, "Ménière's disease"; the second is what surgical approach will give the maximal symptomatic relief with the minimal morbidity and mortality rates.

THE SYMPTOMS OF MÉNIÈRE'S DISEASE

In 1861 Prosper Ménière published a series of papers describing a hitherto unrecognized group of people who had the symptoms of vertigo or dizziness, nausea and vomiting, in whom he felt the causative lesion was in the inner ear and not "in the cerebellum or cerebellar peduncles." Previous to this time these symptoms had been classified under the term "apoplectiform cerebral convulsions." Ménière pointed out that the distinguishing features which differentiated the group he was describing from the general group were signs and symptoms of cochlear involvement and a tendency to remissions and recurrences extending over a period of months or years. In most of the other disorders in which vertigo or dizziness, nausea and vomiting were present, tinnitus and deafness were not present and there was no tendency to recurring attacks, but rather a single attack was followed by a slow and gradual recovery.

By reviewing Ménière's papers it is possible to outline the signs and symptoms which he felt were characteristic in the group of people he was describing.

1. In a person without previous signs or symptoms of ear disease a bruit might occur in both but usually only in one ear. This tinnitus tended to increase during the "crisis" of the disease. It might have periods of remission but tended to be continuous until the hearing was completely lost, which, however, might not occur for a period of months or usually of years.

2. "Crises" or "attacks" characterized by severe vertigo or dizziness tended to occur from time to time, lasting from several hours to a day. These crises were of four types.

- A. The patient, without warning and without obvious cause, might be seized with a terrifying sensation of whirling. When he was lying in bed with the eyes closed, usually on the sound ear, the sense of spinning would be less marked (subjective vertigo) but, when the eyes were opened, surrounding objects would appear to be violently whirling about

(objective vertigo) and the patient would be seized with nausea and vomiting. Since the patient tended to lie on the sound ear, he would appear to be completely deaf unless the head were turned so that the hearing in both ears could be tested. Associated with vertigo was a condition of extreme weakness, rapid pulse and cold sweat which Ménière termed the "syncopal state."

B. The patient without warning would suddenly fall to the ground as if struck on the head and after reaching the ground would experience the same sensations described in the previous paragraph.

C. Instead of the sensation of angular acceleration about an axis the patient might experience the sense of moving violently up and down. One of Ménière's patients described the feeling as that of being on the bridge of a ship at the mercy of a stormy sea. This sensation also was associated with nausea, vomiting and the syncopal state. This has been termed an "utricular attack" by Tumarkin.

D. The patient might have the sensation of being violently forced to one side, and not only felt, but was, unsteady. On attempting to walk he might run into a wall or a tree.

Ménière also noted that between these crises, or attacks, which might last from several hours to a day, the patient might have a mild vertigo on sudden turning of the head or change of position, such as lying down on, getting up from, or turning over in, bed, so that he was maintained in a constant state of anxiety lest he might be about to experience a major "crisis" or attack.

From this résumé it may be seen that Ménière had a very clear comprehension of the symptom complex that came to be called after his name.

Crowe pointed out that the symptoms were so invariable that they must originate from a common cause and for this reason the condition should be termed a "disease." Unfortunately Ménière died in the year following publication of this series of papers, and a great deal of confusion in regard to recognition of the disease he had described was occasioned very early in its course by two serious misquotations or misunderstandings of his papers.

The first misquotation was that Ménière had stated that a hemorrhage into the labyrinth was the cause of the disorder or disease; the second was that he had presented as the pathologic basis of the group of symptoms he described the necropsy findings of a blood-tinged serous exudate in the semicircular canals of a young girl who had been struck with sudden deafness, violent vertigo, nausea and vomiting and had died on the fifth day of her illness.

I have found both these statements to be contrary to fact. One or both of these misquotations have continued to head nearly every account

of "Ménière's disease," however, and as a consequence more and more conditions of such a nature that, whatever they might be, they could not possibly be Ménière's disease, have been included under this term. Thus, any condition in which the symptoms of vertigo, nausea and vomiting appeared was termed "Ménière's disease" or more frequently, "Ménière's syndrome" or "Ménière's symptom complex." These latter terms were substituted for another "wastebasket" diagnosis, that of "apoplectiform cerebral congestion," under which these conditions had been lumped before Ménière's day.

THE PATHOLOGY OF MÉNIÈRE'S DISEASE

Ménière stated that in his opinion the condition he was describing was a functional disorder of an unknown type having its site in the semi-circular canals. He pleaded with otologists to secure specimens for microscopic study so that the pathologic changes could be ascertained definitely. A deaf ear was turned to this plea, however, and it was not until a neurosurgeon supplied the material from 3 patients with authenticated Ménière's disease, who had died of hemorrhage into the cerebellum after intracranial division of the eighth cranial nerve that the establishment of a pathologic background was attempted. This was said to be a gross dilatation primarily of the ductus cochlearis, secondarily involving the saccule and utricle. Some atrophic changes were found in the stria vascularis and in the organ of Corti. There was a notable absence of any inflammatory change. This pathologic description has been subsequently confirmed by many observers both in this country and abroad, and it is now generally held that the pathologic picture in Ménière's disease has been definitely established. Lermoyez, however, in 1919 suggested that Ménière's disease must be a question of local angiospasm in persons having an exaggerated susceptibility toward external excitants and internal irritants. He stated that one may conceive of a spasm being able to close the internal auditory artery or one of its branches.

1. Spasm of the trunk of the internal auditory artery would affect simultaneously the equilibrial labyrinth and the cochlea, which would manifest their trouble by the complete triad of Ménière.

2. Spasm of the branches of the internal auditory artery to the vestibule might precipitate paroxysmal vertigo without a concomitant effect on the hearing.

3. Spasm of the internal auditory artery beyond the separation of the vestibular branches could provoke a sudden but evanescent deafness involving violent tinnitus but no vertigo.

Lermoyez pointed out that in a superficial vasospasm such as Raynaud's disease it could be observed that the sudden shutting off of the

circulation as well as the sudden return of the circulation could produce pain. Since the vestibular nerves are modified sensory nerves, he felt that the "pain" of the vestibular nerve was vertigo and the "pain" of the auditory nerve was tinnitus. Lermoyez described a group of patients with increasing illness and progressive deafness, then suddenly vertigo appeared and hearing returned. He expressed the belief that this syndrome could be caused by the sudden release of *vasospasm* which had affected the internal auditory artery.

These varieties of Ménière's disease are occasionally seen in any extensive practice, yet they appear to constitute less than 10 per cent of the entire group. Nevertheless they should not be excluded from consideration as an insistence on the presence of a serous transudate in the membranous labyrinth would do.

Wittmaack stated that hydrops of the labyrinth is, in general, considered to be the slightest expression of disease in the labyrinth that can be produced by an inflammatory stimulus (the concept of inflammatory stimulus should be considered in its broadest sense). It could be considered a parallel phenomenon to acute hydrocephalus externus and the so-called meningitis serosa.

Wittmaack felt that his newer experimental investigations strongly favored the viewpoint that secretion of fluid into the labyrinth without an accompanying secretion of serum protein should be interpreted as a completely hypersecretory and therefore "hydropic" phenomenon, and for this reason must be called "hydrops" rather than "serous labyrinthitis." The difference in the two conditions, according to Wittmaack, lies in the fact that in one case the secretory epithelium produces an unusually thin secretion qualitatively resembling physiologic salt solution while in the other case transudation of blood serum follows capillary dilatation and slowing of the circulation which is also a typical irritative reaction of the vascular system in the mesenchyme.

Considering the fact of the priority of Wittmaack's use of the term, "hydrops of the labyrinth" cannot be used with propriety as a synonym for "Ménière's disease." In addition to this, the physiologic mechanism active in Ménière's disease is probably a "spastic-atonic" state of the capillaries of the stria vascularis. This would result in a transudate from the capillaries rich in serum protein and the condition would therefore be according to Wittmaack's classification, a serous labyrinthitis (or labyrinthosis). Wittmaack pointed out that the stimulus for the production of either hydrops or serous exudate into the labyrinth is not direct unmediated bacterial invasion. The vascular reaction is one that normally occurs in the terminology of Selye to any alarming stimulus. Since in Ménière's disease the fundamental process appears to be an individual tendency to hyperreact focally to a normally minimal stim-

ulus, Wittmaack's investigations should hold in regard to its development. I feel, therefore, that one should classify Ménière's disease as being with or without serous labyrinthitis, depending on whether the disorder was accompanied by a fluctuating deafness, resulting from pressure on Corti's organ, or not.

ADDITIONAL SYMPTOMS OF MÉNIÈRE'S DISEASE

Little has been added to Ménière's original description of the symptoms. Crowe noted a marked variability in the hearing in the early stages of Ménière's disease, and Dederding and Lillie, Horton and Thornell noted that the loss of hearing can be restored under treatment.

Shambaugh noted that when only one ear is involved or when there is a considerable difference in hearing in the two ears, diplacusis binauralis dysharmonica is present. He felt that increased pressure of the endolymph results in an edema and loading of the vibrating membrane in the inner ear so that a pure tone will be thrown further toward the basal coil, resulting in a given tone being heard as of higher pitch in the involved than in the uninvolved ear.

Brunner and others have noted that whenever vertigo of any extent and duration is present it will be accompanied by nystagmus of the third degree.

Possibly most important of all, Mygind and Dederding have described the "associated" symptoms of Ménière's disease. These consist of: (1) headache of a vasodilating or myalgic type on the same side as the diseased ear; (2) vasomotor rhinitis, sometimes homolateral; (3) angioneurotic edema, usually on the homolateral side and frequently in the region of the affected ear; (4) chilliness with cyanosis of the extremities occurring in response to a stimulus not effective in producing this reaction in normal persons; (5) fatigability, irritability, depression and impairment of memory, phenomena which show the same capricious changes as the deafness.

Mygind and Dederding also observed that patients with Ménière's disease tend to suffer from gastro-intestinal disturbances, oliguria and deficient perspiration, that they tend to feel better in summer than in winter, worse after meals, and that their symptoms tend to show improvement with loss of weight and worsening with increase of weight.

It is on the basis of these observations, as well as of capillary studies, by Müller, Paresius, Brown and Sheard and others; of studies of the autonomic nervous system and its behavior by Petersen; and of studies of the alarm phase of the general resistance mechanism by Selye, that the hypothesis that Ménière's disease is an interstitial edema due to a localized capillary dysfunction mediated by the parasympathetic or cholinergic fibers of the autonomic nervous system has been suggested.

A localized vasomotor dysfunction leading to pathologic changes of this type is known as a physical or intrinsic allergy according to the nomenclature suggested by Duke. Upon this hypothesis all successful medical treatment of Ménière's disease has been based.

CONDITIONS WITH WHICH MÉNIÈRE'S DISEASE MAY BE READILY CONFUSED

If the original clinical description of Ménière's disease is adhered to, few conditions can be confused with it. This is essentially variable deafness and tinnitus and "crises" of paroxysmal vertigo of the end organ type with remissions and recurrences. Those conditions most difficult to differentiate are as follows:

Positional Vertigo.—Ménière pointed out, however, that positional vertigo tended to be present between "crises" of the disease.

Toxic Vertigo.—Quinine is apparently the drug most likely to produce toxic vertigo in this country, but since the work of Marshall Taylor its use has been greatly diminished. Ménière suggested an association between the appearance of his disorder and the taking of large quantities of quinine. Other drugs, such as the salicylates, are capable of precipitating a Ménière-like crisis. Care should be taken to obtain a history of any drugs taken preceding an attack of deafness, tinnitus, vertigo and nausea.

Tubal Occlusion.—Merica in particular has pointed out that tubal occlusion may simulate Ménière's disease. In most instances the vertigo produced is not severe, the chief symptom being a tendency to stagger toward the affected side in walking. Occasionally, however, violent vertigo and nausea will result. It would seem worth while to inflate the eustachian tubes of any patient suspected of having Ménière's disease.

Psychogenic Vertigo (Conversion Neurosis)—Anxiety and insecurity are likely to be converted by certain persons into a sensation of vertigo. It should be realized that Ménière's disease itself tends to produce anxiety and feelings of insecurity because it produces a much greater psychic shock to the patient than, for instance, an epileptic convulsion. In the crisis of Ménière's disease the mind is perfectly clear and the events of the attack can be recalled without difficulty. As a consequence in many patients who have Ménière's disease psychogenic vertigo develops in addition to the primary disorder so that sometimes it becomes difficult to tell from the patient's account of an attack whether it was an actual Ménière's attack or the conversion of a psychic state that is being described.

Other conditions such as Bruns' syndrome, particularly when it is caused by multiple sclerosis, hypersensitive carotid reflex, vertiginous epilepsy, spasmodic occlusion or thrombosis of the branch of the postero-

inferior cerebellar artery supplying the vestibular nuclei or meningiomas at the cerebellopontine angle have been confused with Ménière's disease. In these the cardinal sign of deafness in the involved ear is absent.

AUDIOMETRIC TESTS

The deafness in Ménière's disease is of a base type with decreased bone conduction. Mygind pointed out that this is an inner ear conduction deafness, being due to an increased pressure in the endolymph. The endolymph is not a neural structure but part of the conducting mechanism of the inner ear and therefore deafness produced by a disorder of the perilymph or endolymph should not be referred to as a nerve or perceptive deafness. This type of deafness is characteristic of hydrops of the endolymph, being found otherwise only in an occasional case of tubal occlusion. It is usually better brought out by tuning fork tests than by the audiometer. With the audiometer it is more noticeable in the bone conduction curve than in air conduction.

FUNCTIONAL TESTS OF THE LABYRINTH

I have found that caloric testing by Kobrak's minimal stimulus technic, using 5, 10 and 15 cc. of ice water, is useful in testing the functional condition of the equilibrical labyrinth. In Ménière's disease the usual finding is a hypoactive labyrinth on the involved side. Occasionally in an early stage of the disease normal labyrinthine function will be indicated by the test used. In my experience a hyperactive labyrinthine reaction is rarely found in a case of definitely established Ménière's disease.

SELECTION OF SURGICAL PROCEDURE

In 1871 Knapp compared the causation of Ménière's disease to that of glaucoma. In 1897 Cheatle expressed a similar opinion, suggesting that Ménière's disease may be caused by increased pressure of fluid in the labyrinth resulting either from increased production or decreased drainage of the perilymph. On the basis of these hypotheses he suggested that Ménière's disease might be relieved by decompressing the perilymph by opening through the bony labyrinth. This suggestion was not followed out, however, until 1904. In August of that year, by a curious coincidence, the first accounts of two operations to relieve aural vertigo and tinnitus, one by opening the semicircular canals, the other by intracranial division of the auditory nerve, appeared in the *Journal of Laryngology and Otology*. Parry based his operation of division of the auditory nerve on a fancied analogy between Ménière's disease and tic douloureux.

Destructive Labyrinthotomy.—Milligan described the procedure of

opening the bony labyrinth for relief of the symptoms of Ménière's disease in the same issue Lake had published an account of an operation on the labyrinth for the relief of Ménière's disease in June of the same year but in 1906 he gave Milligan the priority as far as the time of the performance of the operation was concerned. In this later paper Lake stated that he would not discuss the various methods which had been described for the division of the auditory nerve within the skull, not on account of the high mortality rate which had followed these operations but because it seems that we have every reason to believe that where intracranial division of the auditory nerve has been successful, direct destruction of the posterior half of the membranous labyrinth would have been equally efficacious as far as vertigo is concerned. What was of greater importance still, Lake believed, was that the operation of destructive labyrinthotomy appeared to be without risk to life. Lake reported data on 6 cases in which the operation was successful in so far as vertigo was concerned, but was without relief to the intolerable noises in the head. In 1910, Lake reported data on 4 more cases of Ménière's disease in which the operation had been successful, bringing his total to 10.

In 1924, Milligan reported that after destructive labyrinthotomy on the affected side 20 patients who had Ménière's disease were completely relieved of vertigo with complete relief of tinnitus in 40 per cent and partial relief of tinnitus in an additional 20 per cent. All patients were completely deaf in the ear on which the operation had been performed.

After this paper there were only sporadic reports of treatment of Ménière's disease by destructive labyrinthotomy in the literature until 1943. In that year Day reported complete relief of vertigo in 7 cases in which labyrinthotomy, followed by destruction of the membranous labyrinth by electrocautery, had been done. Day reported temporary retention of hearing in the ear on which operation had been performed in 4 cases but the hearing was permanently maintained in but 1. Day reported that the hearing retained after operation is not useful. In 1 case of Ménière's disease in which the origin of the symptoms appeared to be bilateral, partial relief of symptoms was secured by unilateral labyrinthotomy. Day reported that control of the symptoms by medical means, which had been impossible before the unilateral labyrinthotomy, was readily accomplished afterward.

Cawthorne in 1943 reported the effect of labyrinthotomy followed by seizure and removal of the membranous horizontal semicircular canal in 48 cases of Ménière's disease. Relief of the vertigo was secured in all of these cases.

In 1946, Day reported complete symptomatic relief in 50 additional cases of Ménière's disease in which destructive labyrinthotomy by his technic had been done. In the same year Cawthorne reported uniformly

successful results in 116 patients with Ménière's disease operated on without any untoward results.

Intracranial Division of Eighth Nerve.—In a paper published in 1928 and in papers subsequently published Dandy suggested intracranial division of the auditory nerve as the operation of choice in persistent aural vertigo and may be said to have established the operation in favor for a time. He suggested modification of the procedure consisting of hemisection of the nerve, enough fibers of the auditory division being spared so that cochlear function would be preserved.

Crowe reported, however, that in only 22 per cent of the cases in which Dandy had performed hemisection of the eighth cranial nerve (cases which Crowe had subsequently reviewed) was hemisection successful in preserving hearing in the ear on which the operation had been performed. In the remaining four fifths of the patients, hearing was found to be lost immediately after operation or deteriorated rapidly after the procedure.

In suggesting hemisection Dandy was working on the basis of the hypothesis that Ménière's disease was analogous to trigeminal neuralgia and that a degenerative process in the fibers of the vestibular branch of the eighth cranial nerve was responsible for the symptoms. The weight of evidence as to the cause of Ménière's disease appears to be strongly against this hypothesis.

In consideration of the preponderance of cases showing evidence of serous labyrinthitis among authenticated cases of Ménière's disease, one is surprised by the fact that in approximately a fifth of the cases of presumed Ménière's disease in which Dandy performed hemisection of the eighth cranial nerve useful hearing should have been preserved in the ear on which operation was done.

Hallpike and Cairns were the first to suggest that the underlying pathologic process in Ménière's disease appears to be an increased volume and pressure of the endolymph having its primary expression in the ductus cochlearis. There would seem to be nothing either in the surgical procedure of intracranial division of the eighth nerve or in destructive labyrinthotomy to terminate the fundamental physiologic dysfunction which is producing the lesion when such a process is present. The natural tendency should be considered to be a continuation of the abnormal pressure on the cells of the organ of Corti, which has been shown to lead to their eventual atrophy and death. It is known that surgical procedures have a temporarily inhibiting effect on the expression of allergic disease, and I have presented evidence to indicate that Ménière's disease is a form of physical allergy. This inhibiting factor might account, therefore, for a temporary remission of the endolymphatic hydrops responsible for the symptoms of Ménière's disease in a given case. On the other hand

the confusion in diagnosis introduced by the concept of Ménière's symptom complex or syndrome, in which are included all cases exhibiting vertigo, nausea or vomiting without regard to the presence or absence of signs of cochlear involvement, may have been a factor in producing this result. In some cases which were not in fact representative cases of Ménière's disease operation may have been performed under this diagnosis.

Another possible reason for the lack of success of the procedure of hemisection has been demonstrated by Rasmussen in his study of the funicular pattern of the eighth cranial nerve. Rasmussen stated that in only a fair proportion of the nerves that he studied microscopically were two grossly distinct trunks formed. These rarely represented a true division into cochlear and vestibular fibers, for in nearly all such cases there were obvious vestibular fibers in the cochlear trunk. He stated that in one such nerve sectioned nearly one fifth of the apparent cochlear nerve was occupied by vestibular fibers. In his opinion in resection of what was presumably the vestibular nerve in this instance, about one fourth of the vestibular fibers would escape being cut. Rasmussen also showed that in nerve trunks where no apparent anatomic division is present the division of fibers is such that many vestibular fibers would remain uncut by the technic suggested by Dandy. It appears on the other hand that if the surgeon tries to make sure that the vestibular fibers are all divided, not enough cochlear fibers would remain in most cases to carry on cochlear function.

Walsh and Adson in reviewing their results following intracranial division of the eighth cranial nerve reported that in those cases in which hemisection was done, when hearing was preserved vertigo was not abolished and when vertigo was abolished, hearing was not preserved.

Putnam stated that intracranial section of the eighth nerve was neither as easy, rapid nor safe as some accounts would lead us to believe.

Cairns estimated the mortality rate in intracranial division of the eighth nerve to be in the region of 5 per cent with a rather large morbidity rate due to injury of other closely associated cranial nerves. Although he was one of the earlier neurosurgeons to advocate intracranial division of the eighth nerve in cases of Ménière's disease, he appears to have abandoned this procedure in favor of the destructive labyrinthotomy done by his colleague, Cawthorne.

Previous to the introduction of the sulfonamide compounds and the antibiotics the argument had some validity that opening up the perilymphatic and endolymphatic spaces when nature had not formed a protective leukocytic barrier to the invasion of the arachnoid sac might expose the patient to labyrinthitis and meningitis from organisms reaching the middle ear through the eustachian tube or peritubal lymphatics.

More than 50 such operations had been reported, however, without such a complication developing. Since the introduction of these drugs this fear has been demonstrated to have no basis whatever as more than 300 cases of destructive labyrinthotomy have been reported without death from infection or other causes.

Northington and Barrera in studying the responses of monkeys after extirpation of the labyrinth as well as after section of the eighth nerve, both unilateral and bilateral, confirmed the findings of Lake in regard to the human. They found the results as far as labyrinthine physiology is concerned the same whether the labyrinth in question was destroyed or the eighth nerve was sectioned.

In the surgical treatment of Ménière's disease we have the choice between a major surgical procedure involving craniotomy with the opening of the arachnoid sac and carrying relatively high mortality and morbidity rates and a minor surgical procedure done through the mastoid which does not open the arachnoid sac and has a negligible mortality rate and a very small morbidity rate. It has been observed that both procedures produce the same clinical and physiologic effects. From the standpoint of the well-being of the patient it would appear, therefore, that destructive labyrinthotomy is the procedure of choice in the average case. Only in the small group of cases of Ménière's disease in which the hearing remains good, owing to lack of spasm of the cochlear branches of the internal auditory artery, would the question arise as to whether the operation should be hemisection of the eighth nerve or destructive labyrinthotomy. It is a question as to whether the chance of preserving the hearing, which appears to be in the neighborhood of 25 per cent, offsets the mortality and morbidity rates of the intracranial procedure. This question is, and probably always will be, debatable.

INDICATIONS FOR DESTRUCTIVE LABYRINTHOTOMY

The type of case in which surgical intervention can be expected to produce symptomatic relief and the type of surgical procedure best serving the continued well-being of the patient having been decided on, the specific indications for surgical intervention in the individual case may be considered.

Factors to be taken into consideration first are the general condition, the age and the economic and social status of the patient. That the general condition of the patient should be good enough to withstand surgical treatment goes almost without saying. In addition to this the expectation of life should be sufficiently long to make the duration of relief from symptoms as a result of the surgical procedure seem worth while. Because Ménière's disease has as its basis a localized type of autonomic dysfunction otherwise known as a physical allergy, a tendency

toward which appears to be inherited, a cure of Ménière's disease, in the sense that the fundamental basis of the disorder can be eliminated, reasonably cannot be expected. The medical treatment can accomplish no more than to throw the patient into a remission, which occasionally can be maintained by dietary and therapeutic measures for an indefinite time, but the tendency toward recurrence of symptoms under the stress of infection, fatigue, emotional perturbations or endocrine disturbances such as the menopause is always present. It has been said that the symptoms of Ménière's disease may be muffled by medical treatment but not abolished. Therefore, if the disease is to be controlled by medical treatment, the patient must be in a situation and an economic status such that he or she can afford the time and attention necessary for more or less continuous treatment with more or less frequent medical consultation. In a laborer upon whom depends the support of a family the most sensible procedure might be a surgical intervention in any case.

In addition to this the psychosomatic effect of an operation on the patient ought to be considered. If the patient can be reasonably assured that as a result of an operation "crises" of the disease will not return, a very real anxiety and feeling of insecurity will be relieved. In certain patients the psychosomatic aspects of Ménière's disease assume major importance. In such patients surgical intervention should be given careful consideration even though relatively good results are being obtained by medical therapy.

In considering the propriety of surgical intervention the possibility of a recurrence of the disorder at a later time in the uninvolved ear becomes a question of importance. The evidence that Ménière's disease is a localized type of autonomic dysfunction, the so-called physical or intrinsic allergy, is very impressive. It is well known that in the physical allergies of the head, which include the myalgias, the vasodilating pain syndrome and Ménière's disease, the major expression of the disease is, and tends to remain, unilateral. Instances in which the disease involves both sides of the body or, after occurring on one side, later involves the other side, do occur, but are rare. Thus in Ménière's disease in only an occasional instance will an expression of the disease sufficient to produce the distressing "crises" be found on both sides even though Cawthorne and Hallpike have found minor cochlear evidence of the disease to be present on the "uninvolved" side in about 85 per cent of their cases.

Instances in which after one ear has been destroyed the disorder has later appeared in the other ear are not reported in the literature and have not occurred in our experience at the Clinic. Therefore, the appearance of major symptoms originating from the opposite ear after surgical intervention on one ear need rarely be anticipated. It would seem, therefore, that the incidence of this complication would be so low

that it can be ignored in considering the suitability of a patient with Ménière's disease for surgical treatment.

In bilateral Ménière's disease the question as to whether operation should be performed on one or both ears must be considered.

The purpose of the whole integrated mechanism of exteroceptive and proprioceptive stimuli of which the equilibrical labyrinths are the master organs is to maintain an intact and steady visual panorama on the retina. As Tait stated, "It is one of the marvels of our organization that the three pairs of canals working in association with the four straight and two oblique muscles of the eye present us (or any vertebrate) with an adequate view of the surroundings even though the pedestal or support of the registering camera be temporarily rocking or swinging." If only one labyrinth be destroyed, adequate or complete compensation for the destroyed end organ may take place after an interval of a year or more. The unsteadiness present in a patient during the period that such compensation is being developed has been termed by Kerrison, the "vertigo of labyrinthine destruction." He mentioned the case of a steel construction worker, who was able to resume work on the skeletons of tall buildings within a year after destruction of one labyrinth. §

When both labyrinths have been destroyed, however, such compensation does not appear to take place. Dandy reported that division of both vestibular nerves is attended by jumbling of visual objects while the patient is in motion but that as soon as the patient is at rest the visual panorama is again perfectly clear. He noted that one of his patients was unable to see along a straight line. He also stated that the patient is uncertain when walking in the dark. He found that both conditions were permanent. These findings would indicate that a patient on whom a bilateral destructive labyrinthotomy had been done would be confined to a completely sedentary occupation, could walk only with difficulty and could not drive a car. It seems questionable if a surgeon often would be justified in producing such a helpless person, especially when one considers, as Day originally suggested, that in bilateral Ménière's disease, if destructive labyrinthotomy is done on one side, the symptoms arising from the opposite side are much easier to control by medical treatment. These facts would seem to weigh against the performance of bilateral labyrinthotomy even in a deaf-mute, an instance of which was reported by Milligan, where the factor of resulting complete deafness would not need to be considered.

After destructive labyrinthotomy in unilateral disease transient dizziness and diplopia are the rule, the degree to which postoperative signs are manifested depending on the degree to which the end organ had become destroyed during the progress of the disease. The vertigo usually reaches its peak about forty-eight hours after the operation and

has usually completely disappeared at the end of a week to ten days. The dizziness of labyrinthine destruction takes longer to disappear but Cawthorne found that 116 patients on whom destructive labyrinthotomy had been done were glad with very few exceptions to return to work within two months of the operation. The factor of persistent dizziness or vertigo should not be a deterrent, therefore, in doing unilateral destructive labyrinthotomy.

In most instances patients should have had a trial with medical measures before destructive labyrinthotomy is suggested, except in those instances in which the hearing has been so far destroyed by the disease that hope of restoring useful hearing has been lost and in which the type of attack is such that it constitutes a source of danger of serious injury to the patient. The sudden falling attacks in which the patient drops to the ground "as though struck on the head" are of this nature, as patients with this type of disorder have been seriously injured or even killed as the result of such an attack. Since medical treatment cannot give any assurance that an occasional attack will not occur, a patient with these so-called "utricular" attacks should be submitted to surgical treatment as soon as possible.

When there is a possibility of restoring useful hearing, attempts at relieving the condition by medical therapy should not be abandoned too soon. Horton has found that the first evidence of restoration of hearing may not appear until after four to six weeks of vigorous treatment. In certain instances, however, even though unproved, the hearing in the involved ear is not useful, being rather in the nature of a handicap. Cawthorne stated that often an important feature of the deafness in Ménière's disease is discomfort due to the distortion of loud sounds, particularly when they are high pitched. Music heard over the radio, children's voices and the rattle of crockery often jar horribly. Other loud sounds, not necessarily high pitched, are likely to cause distress if they are sudden and unexpected. For this reason, Cawthorne felt that the hearing on the affected side may be a definite handicap, and if, as is usual in advanced cases, it is severely impaired, there is nothing to be gained, in cases in which only one side is affected, by trying to save it.

SUMMARY AND CONCLUSIONS

Owing to the confusion introduced by the misquotation of Ménière's original paper it is most important that a careful differential diagnosis be made, for surgical treatment of the end organ is indicated only when the underlying pathologic condition appears to be spasm of the internal auditory artery or its branches.

In deciding between intracranial division of the auditory nerve and destructive labyrinthotomy as the procedure of choice for relief of

Ménière's disease, it would seem that from the standpoint of the well-being of the patient, owing to its freedom from risk of death and relative lack of morbidity, the superiority of destructive labyrinthotomy is incontrovertible.

Patients with unilateral disease in whom the hearing on the involved side is too impaired to be useful and who have failed to respond adequately to medical treatment or who are not so situated as to be able to afford the time and constant attention required for control of the disorder are considered suitable patients for destruction of the end organ.

Patients in whom the type of attack is such as to expose them to the danger of serious physical injury (utricular attacks) are also considered to be suitable patients for destructive labyrinthotomy.

In bilateral Ménière's disease it is felt that owing to failure of compensation after bilateral destruction of the end organ, unilateral labyrinthotomy only should be done.

THE MASTOID INCISION: ENDAURAL OR POSTAURICULAR?

H. I. LILLIE AND KINSEY M. SIMONTON

The principal considerations in planning the incision for any surgical procedure are: (1) adequate exposure of field of operation; (2) return to normal function of structures affected by incision; (3) drainage of wound; (4) repair of field of operation; (5) avoidance of unnecessary postoperative pain, and (6) cosmetic results.

Progress in the field of surgery requires that new methods be considered and used and that the results be compared with those obtained by preceding methods.

For several decades the postauricular incision has been the accepted surgical approach to the structures comprising the temporal bone. It has withstood the test of time and has been proved to be practical by otologists in general over a period of many years. Many variations of the basic incision have been proposed to meet specific needs.

The endaural incision became popular in this country much later than the postauricular incision; hence, total experience with this incision is less than experience with the postauricular incision. In the work by Brand and co-workers, Haworth stated that the transmeatal approach is the oldest approach to the mastoid process of the temporal bone. He stated that it was used by Kessel, who published a paper on mastoidectomy in 1866, and by his pupil, Hoffman; that after the publications of Zaufal and Stacke the postauricular incision became popular, and that Von Eicken and Gompertz revived the transmeatal approach to the mastoid for use with local anesthesia. Whiting credits Petit with having performed several operations on the mastoid prior to 1761. In 1912, the Thies's advocated a method of transmeatal approach to the temporal bone, but the technic was not widely accepted. The current favor accorded the endaural incision for operations involving the temporal bone is largely due to the work of Lempert,^{5,6,7} who, in 1928, 1937 and 1938, described variations of an incision to create an "endaural window" by removal of a block of epithelium from the posterior wall of the external auditory canal. Modifications of the incision which avoid removal of epithelium were proposed by Kettel, Williams, and Whitaker, Juers and Shambaugh. Lathrop stated that sebaceous and ceruminous glands are removed with the block of epithelium, thus reducing the necessity for periodic toilet of the resultant cavity.

Lempert favors use of the endaural approach for all surgical procedures on the mastoid. Johnson and Zonderman, and Woodruff and Henner expressed the opinion that the endaural incision provides adequate

exposure of the cell structure for operation on all parts of the mastoid. They also state that the view of the field of operation is less comprehensive than when the postauricular incision is used. Kettel, Matis and Lathrop favor use of the endaural incision in selected cases. They do not advise it for cases in which endocranial or vascular complications have occurred.

Based on experience with both the postauricular and endaural incisions gained in the operating room, on study of the anatomic structure of the mastoid process, and on observation of patients from the time of operation to that of complete healing, we have made the following comparison of the two incisions in regard to the six points enumerated at the beginning of our report

COMPARISON OF THE INCISIONS

1. Exposure.—It is possible to reach all structures of surgical importance within the temporal bone through either approach. The endaural approach provides shorter working distance to the tympanic cavity, the epitympanic space, the mastoid antrum and the labyrinth. The postauricular incision gives shorter working distance to the mastoid tip, the sigmoid sinus and retrosinus air cells. In our experience the mastoid cell system is more readily exenterated by means of the postauricular incision which provides comprehensive and direct exposure than by the endaural window with limited exposure which restricts the view to only one part of the cell structure at a given time. If the retrosinus cells or the lateral sinus posterior to its upper knee are involved it is very difficult to obtain adequate exposure by the endaural incision. Extensive removal of the tegmen mastoides-tympanicum in cases of epidural abscess is more readily accomplished with postauricular exposures.

The postauricular incision when carried forward above the auricle, with elevation and retraction of the temporal muscle, provides equally direct exposure of the zygomatic cells, mastoid antrum, epitympanic space and tympanic cavity. Working distance from integument to tympanum is greater than with the endaural approach, but, since adequate exposure is provided, this is not a handicap. The working angle in approach to structures in the anterior part of the temporal bone is nearly the same with either approach when the postauricular incision is properly located. The postauricular incision is more readily adaptable to the needs of a specific operation than is the endaural incision.

2. Return to Normal Function.—Neither the endaural, nor postauricular incision traverses structures of functional importance.

3. Drainage of the Wound.—In cases in which pathologic change is limited to the superior part of the temporal bone, drainage can be established through the external auditory canal. Drainage from infec-

tions in the region of the mastoid tip may be effected more directly by the posterior route.

4. Repair of the Field of Operation.—*Acute Mastoiditis.*—Repair after complete mastoidectomy depends on the virulence and destructive power of the infection and on the extent of the cavity remaining after operation. Destructive inflammation after operation is at present readily controlled by chemotherapeutic or antibiotic agents. The cavity remaining after subcortical exenteration of the mastoid cells by the endaural approach is larger than that which remains after transcortical exenteration by the postauricular approach when the bony margins of the cavity are suitably beveled, the tip removed and the posterior wall of the bony external auditory canal is partially removed. Since healing takes place by granulation, the smaller the cavity the more rapidly it is filled and healing is completed.

Chronic Mastoiditis.—After operation for chronic mastoiditis, repair depends on lining the cavity with stratified squamous epithelium. Again, the size of the cavity is a significant factor. The cavity is subject to secondary infection and to excessive granulation, with consequent delay in healing until epithelization is complete.

The endaural approach facilitates subcortical exposure of the mastoid antrum and contiguous areas. Subcortical operation results in a smaller cavity than when the cortex is removed in cases in which the pathologic process is limited to the region of the mastoid antrum. Delay in epithelization of the endaural cavity results from the sharp angle of epithelium at the concha. This may be avoided by undermining the epithelial margin at this point and turning the margin back into the mastoid cavity in the manner described by Whitaker, Juers and Shambaugh.

5. Avoidance of Postoperative Pain.—The principal cause of pain after mastoidectomy is the separation of the sternocleidomastoid muscle from the mastoid tip. This is not necessary in cases of chronic mastoiditis limited to the region of the mastoid antrum. Removal of the mastoid tip facilitates healing in most cases of infection involving the cellular mastoid, and should be done regardless of the approach employed. We have not noted significant difference in postoperative pain in so far as the two types of incision are concerned.

6. Cosmetic Results.—This is a factor of great importance to the patient. Favorable cosmetic results depend upon care in making the incision, avoidance of necrosis of skin margins due to excessive traction or burning with the shaft of the burr, and upon the care exercised in beveling the edges of the bone and in suturing the incision. Sloughing wounds resulting in large depressed scars may be avoided with present-day surgical procedures and drugs. Open packing and secondary suture of mastoid wounds have been abandoned. An enlarged, distorted external auditory meatus is more prominent in location and thus more unsightly

than a depressed postauricular scar. The resultant scar from a properly executed incision of the mastoid in either location is scarcely noticeable.

SUMMARY AND CONCLUSIONS

The choice of incision is dependent upon the anatomic location and extent of the pathologic process present.

Endaural incision is favored for fenestration of the labyrinth for otosclerosis and for operations limited to the region of the tympanic cavity, epitympanic space, and mastoid antrum, including small cholesteatomas

Postauricular incision is favored for complete mastoidectomy in acute mastoiditis, for modified radical or radical mastoidectomy in cases with extensive cholesteatomas or chronic suppuration in unobliterated mastoid cells, for complications involving the dura or lateral sinus, for exploration of the petrous pyramid, and because of greater ease of tight wound closure, for destructive labyrinthotomy

In case of doubt as to the extent of the pathologic process or complications present, postauricular incision is employed because of its greater adaptability

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THE ANESTHESIOLOGIST NOW AND IN THE FUTURE

JOHN S. LUNDY

In this paper I shall try to present some problems in anesthesiology which are of prime concern to the general surgeon at this moment of writing. I shall also endeavor to indicate, as best I may, the direction in which I believe the field of anesthesiology will progress, and the objectives of the future which it is possible to discern, however imperfectly, at the present.

THE PRESENT

The anesthesiologist of today has had an opportunity for formal training that was not available a few years ago. This training should permit him to gain a knowledge and experience with anesthetic agents and methods that ordinarily he would not possess. Hence, today it is truer than ever that the anesthetic agent itself is not the all-important consideration; rather it is largely the skill with which it is used that makes the agent effective. The result is that no one agent or method has quite the importance that it used to have.

At present the anesthesiologist is in a position to offer a very wide choice of anesthetic agents and methods for most operations. He can fit the anesthetic agent and method to the patient's condition, to the operation, to the surgeon's likes and dislikes and he can guard against the danger of fire and explosion. He can help generally with preparation of the patient before anesthesia, regulate the supportive measures needed during operation and give the patient proper care after anesthesia.

If the anesthesiologist can meet the patient beforehand, and the patient develops a liking for him, he has the additional advantage of the patient's confidence, which is most valuable. Even when we who are physicians are faced with the need for medical or surgical attention, we respond better to the opinion and care of the one in whom we have confidence rather than we do to those of a stranger, unless he comes especially well recommended. Actually, it is almost always possible for the anesthesiologist to see the patient before the patient comes to the operating room. Usually, he can see the patient the day before the operation and decide on preliminary medication which will properly augment the anesthetic agent that is to be used.

It is advantageous for the surgeon and his anesthesiologist to make a point of establishing the patient's confidence in the ability of each to give the patient the best of care. Judicious use of preliminary medications, in addition to giving the patient rest and putting him in a good

frame of mind, will tend to bring about a sedative effect which actually reduces the quantity of the anesthetic agent to be used. Individual attention must be given to each patient, so that he will not be overdosed with drugs. This is particularly important when an inhalation or intravenous anesthetic agent is used, because in such an event it is desired to avoid respiratory depression. When local and regional methods of anesthesia are used, however, it may be wished to secure more effect from preliminary medication than would be needed if general anesthesia were to be used. It is in this particular field that the anesthesiologist must exercise his knowledge and experience, since no other member of the surgical team is as much concerned with the problem as he is.

When morphine in solution is employed, it is often accompanied by more morphine depression than when morphine in tablet form is used, unless the dose of the solution is very small. Generally, the likelihood is that the nurse will administer more than the dose ordered, because she must measure the solution in her syringe, in which procedure the tendency is to enlarge the dose, whereas when the tablet form is used the dose is gradually reduced in the handling of it.

Both anesthesiologists and surgeons have noticed that the choice of anesthetic agent is influenced greatly by the patient's choice. Sometimes this is good practice, but sometimes it is not. Acceptance of the patient's choice may make it difficult for the anesthesiologist to produce the results desired by the surgeon and at the same time administer the anesthetic agent the way the patient wishes to have it done. However, in view of the advent of intravenous anesthesia, the introduction of curare and the excellent gas machines that are available, as well as the Magill intratracheal tube, it is now possible to induce anesthesia in a manner more comfortable for the patient. A small degree of general anesthesia, for example, can be supplemented by some method of local or regional anesthesia.

After the patient has received the proper premedication, the anesthesiologist may then proceed with whatever method of anesthesia has been decided on, with the idea that if general anesthesia is to be employed, induction may be carried out in association with a small amount of intravenous anesthesia, such as is produced with pentothal sodium. If the method is to be essentially inhalation anesthesia, then the anesthesiologist must be guarded in the amount of pentothal sodium that is used. As a rule, patients require from 4 to 8 cc. of a 2.5 per cent solution of this agent. The gas mask is applied to the face as soon as the patient appears to be quite sleepy, so that he will have no memory that the mask was put on his face or of when he lost consciousness. From the anesthesiologist's point of view, it is important that the dose of pentothal

sodium be small, because the combined effect of preliminary medication and a fairly large dose of pentothal sodium interferes with respiratory effort, and defeats the effort of the anesthiologist to introduce enough anesthetic in the blood stream to produce relaxation. It is the general anesthetic agent which must be inhaled in sufficient amount to produce the desired results.

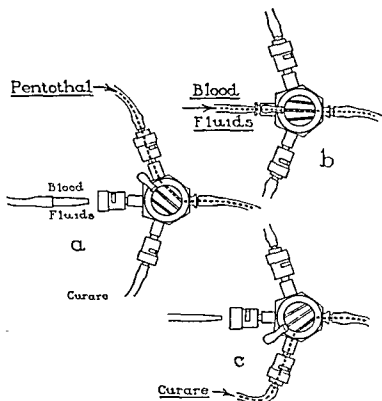
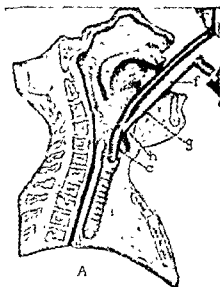


Fig 425.—A modification of Courtin's device for the separate administration, through the same needle, of solutions of curare, pentothal sodium and blood or fluids. (Reproduced, with permission of the publishers, from: Lundy, J. S. Trends in Anesthesiology. Anesthesiology. In press.)

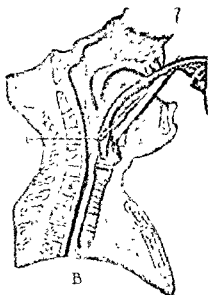
On the other hand, if the anesthiologist wishes to avoid the use of ether and of inflammable gases, it is possible to introduce the solution of pentothal sodium in proper amount from one syringe, and to introduce the desired amount of solution of curare from another syringe. Furthermore, if necessary, supportive therapy can be provided, all through the same needle. A device which facilitates this procedure is illustrated (fig. 425).

Nitrous oxide and oxygen (half and half) may be administered. This provides some analgesic effect, supplements the effect of the other agents, and at the same time gives an abundance of oxygen.

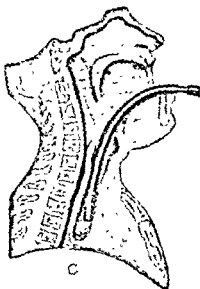
The posture of the patient can be utilized to better advantage and



A



B



C

Fig 426 —Use of an intratracheal tube through the mouth A, laryngoscope and tube, *f*, laryngoscope moves the tongue, *g*, and *h*, epiglottis, so that *c*, the vocal cords are exposed to view, the intratracheal tube is inserted along the blade into the glottis and trachea B, Same as in A, except that *i*, Magill forceps direct the tip of the tube into the glottis C, The full-length intratracheal tube lying in place so its tip almost reaches the bifurcation of the trachea (Reproduced, with permission of the publisher, from Lundy, *J S Clinical Anesthesia* Philadelphia, W. B. Saunders Company, 1912, p 461)

performance of the operation can be facilitated by the use of an intratracheal tube. This tube can be introduced through the mouth (fig 426) or the nose, as illustrated (fig. 427) The use of an intratracheal tube often

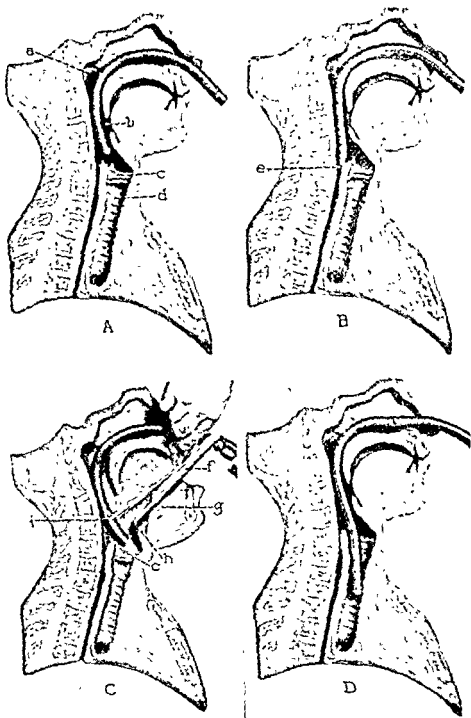


Fig. 427.—Use of an intestinal tube as a nasal tube.

Nasal tube properly placed, the tip lying midway between the glottis and the bifurcation of the trachea. (Reproduced, with the permission of the publisher, from: Lundy, J. S. *Clinical Anesthesia*. Philadelphia, W. B. Saunders Company, 1942, p. 458.)

As and
vision,

permits the surgeon to have an operative field that is not interfered with by the anesthetist's mask or his hands. The airway is excellent and aspiration by the patient of material from the stomach into the trachea usually is prevented. Aspiration by the anesthesiologist of material in the tracheobronchial tree is expedited, because a catheter can be passed through the intratracheal tube for this purpose.

It is important for the anesthesiologist to see that his patient is placed in such a position on the operating table that the vital functions are not interfered with, for example, a patient who has a cardiovascular condition may be placed on the table and maneuvered into a relatively comfortable position before anesthesia is begun. In many instances the patient himself is the only one who can be certain that the position is one which he can tolerate. If he can tolerate the position when awake, he probably can tolerate it when he is unconscious.

Methods for anesthetizing children sometimes must be modified to meet the requirements of the small patient. There are attachments and devices which permit the use of modern anesthesia equipment not only for adult persons but also for children and babies.

Supportive therapy at present consists largely of the use of solutions of crystallized material, blood and plasma. The introduction of the Rh factor into the transfusion of blood has complicated the picture somewhat, and the use of plasma has not been without some difficulties in respect to virus hepatitis. Currently, irradiated plasma is being made available, and it is said to be free of this hazard.

When the transfusion of blood is necessary, the anesthesiologist should know the group of the blood of the patient and whether his blood is Rh positive or Rh negative. Blood can be preserved for only a limited period. Refrigerators are necessary to keep it chilled, and elaborate records must be kept in respect to the donor. The anesthesiologist must be prepared to take the responsibility of using blood that is not exactly suitable for the patient, should such an action become imperative.

At the time of operation it will be found that some patients have veins into which injection cannot be made easily, or that some are children whose veins are difficult to find. In such an event a 17-gage needle can be introduced into a vein after anesthesia has been induced since the veins are then well dilated. The needle may be left in place during the operation, so that if blood is needed it may be administered by gravity. At the end of operation a small polythene tubing may be introduced into the vein through the needle and the needle may be removed (fig. 428). This tubing permits the administration of fluids by gravity or blood or plasma given by syringe for a period of time. Sooner or later the vein may react to the tubing, but for the most part, in difficult situations, the tubing serves a very useful purpose.

For most busy hospitals the addition of a postanesthesia room is of importance. When such a room is available the anesthesiologist sees each patient before he leaves the operating room, and decides whether the patient is sufficiently awake and whether his condition is good enough to justify his return to his own room. If not, the patient should be sent to the postanesthesia room (now becoming known as the "P.A.R."), and there trained personnel care for the patient until his condition is such that he may be returned to his room and will not be a burden to the floor nurses.

I may say that I have had a very pleasant experience with this sort of procedure, for I established such a room on March 17, 1942, at St. Marys Hospital in Rochester, Minnesota. Through that room have gone a great many patients. The room and its benefits have been a great satisfaction not only to me, to the hospital and to my surgical associates,

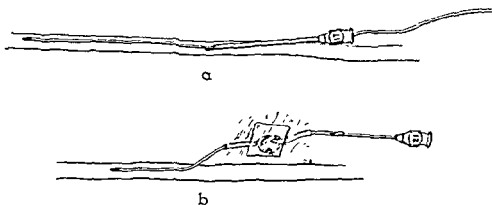


Fig. 428.—a, A 17-gauge needle is first inserted in a vein; then a small section of polythene tubing into the vein through the 17-gauge needle; b, the needle has been removed from the vein and the section of polythene tubing remains for the administration of fluids by gravity, or blood or plasma by means of a syringe.

but also to the nurses on the floor. The patients go through the immediate postoperative period while they are recovering from the anesthesia in a place in which all necessary facilities exist, such as suction, oxygen, beds with sideboards and all the devices that may be needed in the event of complications. This room is visited every hour on the hour by a physician from the Section on Anesthesiology who keeps the supervising anesthesiologist informed as to the situation in the postanesthesia room. A trial of this arrangement is all that is necessary in order to convince those concerned of the desirability of it.

The fact that the anesthesiologist uses needles in his daily practice makes it logical for him to be the person to expedite intravenous therapy in an institution. Such work is of real assistance, especially in difficult situations. The anesthesiologist may be equally valuable when lumbar puncture is difficult. Psychiatrists and neurologists who employ shock therapy will find it desirable to employ the anesthesiologist to administer

... will not
 ... that the occurrence of fractures
 a ... use of curare may be held to a minimum. Again, if an untoward reaction should occur in a hypersensitive person the anesthesiologist will have with him suitable equipment and drugs for resuscitation and support of the patient.

In the control of patients suffering from conditions such as tetanus or some convulsive disturbance it is logical, also, for the anesthesiologist to be the person to bring the patient under control, at least temporarily, until effective treatment can be instituted for his disease or condition. When a patient is suffering from an overdose of drugs, for instance, or increased intracranial pressure or some condition which interferes with respiration, the anesthesiologist is prepared to introduce an intratracheal tube and to carry on artificial respiration for a considerable period or until effective treatment can be instituted. In the immediate postoperative period the anesthesiologist usually can aspirate excessive mucus or fluid from the tracheobronchial tree, he can draw off air from the thorax in the presence of pneumothorax or he can even draw off fluid if acute hydrothorax is present.

THE FUTURE

It is reasonable to suppose that the anesthesiologist of the future will be superior to most anesthesiologists of today in respect to the body of knowledge he will possess and the equipment that will be available to him. New anesthetic agents constantly are being developed; moreover, it is possible that new methods will permit the employment of old agents to greater advantage than is possible at present.

A good example of what a new method can do for an old anesthetic agent is seen in the use of procaine hydrochloride for continuous spinal anesthesia, in which the method itself enables procaine hydrochloride to give results that are better than could be obtained by the single-dose method with either procaine hydrochloride alone or any of the long-lasting substitutes that have been developed lately.

The introduction of curare for the purpose of producing relaxation has made it possible to employ the combination of pentothal sodium and nitrous oxide and oxygen, so that the hazard of fire is almost eliminated and yet the benefits and virtues incident to the use of these mild anesthetic agents can be retained while the surgeon is provided with a relaxation necessary for accomplishment of his work. In the future it is probable that a more potent relaxant will be found than curare is now. At the moment, metcurare is being reinvestigated on the theory that it may be less depressing to respiration than d-tubocurarine. Myanesin is

being reinvestigated to test the possibility that in certain conditions, and especially spastic states not necessarily requiring surgical treatment, it will produce some degree of relaxation and can be given by mouth. These investigations may lead to important developments. For instance, a better intravenous anesthetic than pentothal sodium may be developed, although pentothal sodium seems to be a very effective agent.

Doubtless the efforts of the anesthesiologist of the future will be to increase his value as a member of the surgical team, as a member of the hospital staff and as a member of the community. He will familiarize himself with cardiology to such a point that he can co-operate intelligently with the cardiologist, understand the cardiologist's point of view and by means of his help develop a device which will permit him to recognize a cardiac condition from moment to moment during operation, so that the patient may be brought through the whole period of surgery and the postoperative period with as much certainty of safety as will be possible.

I hope to see a device in the operating rooms, where it could be viewed by anyone, which will give information concerning the heart, its rate, its rhythm and its condition, as far as possible. It is to be hoped, similarly, that some device for reading blood pressure will be developed for use in the operating room and immediately after operation, so that the blood pressure may be noted instantly at any time. I believe that a device for indicating the oxygen content of arterial blood will be perfected rapidly; already reports on new devices indicate that the time is not far distant when such devices will be available generally.

Devices now in use furnish data which indicate that in the future the anesthesiologist will know exactly how much of the various agents, such as ether, nitrous oxide and oxygen, are in the breathing bag in the gas machine at all times. Use of the electro-encephalogram in connection with anesthesia is being studied; already an electro-encephalographic pattern has been described which would indicate that at various levels of anesthesia the activity of the brain is depressed proportionately. The question of the genesis of convulsions which occur during anesthesia perhaps will be elucidated by use of the electro-encephalogram.

The importance of aids such as these, especially in operations on infants, cannot be exaggerated. The condition of the small child in the midst of a major operation under the influence of general anesthesia is a problem that taxes the ability of the best anesthesiologist. Probably there is no one who would not recommend any of the modifications of the devices already mentioned which would make it clear what the blood pressure and heart rate are throughout the operation.

New vasopressor agents are being introduced from time to time, and although new ones thus far do not seem to offer any great advantages

over the older ones, the search nonetheless is very worth while. Sooner or later, as a result of such intensive work, something especially valuable may be discovered

So far as substitutes for plasma are concerned, there is considerable promise. These substitutes at the moment will not suffice in the event of a large loss of blood, yet they do offer much promise. At present the need for blood is being met either through the efforts of the American Red Cross or through local efforts, but the problem certainly is not a simple one. *By means of community contributions the efforts of the Red Cross are supported and voluntary donors are used. In some institutions, such as the one with which I am associated, donors are paid for the blood they supply.* The expense of the laboratory tests, maintenance of the collecting center, and payment of the personnel necessary for handling of the blood are formidable outlays. The work must be carried on meticulously. Dangers in the matter of use of wrong blood or unexpected reactions to blood arise from time to time. The use of plasma has been accompanied by the danger of transmission of virus hepatitis, with fatal outcome. As I said previously herein, the irradiation of plasma is said to have eliminated this danger, but it has also increased the cost of plasma.

In time of war a substitute for blood or plasma would be very important. Such a need arose in Germany in World War II and a substitute was made by Weese—a drug, polyvinyl pyrrolidone, which he called "kollidon." This drug, dissolved in a 2.5 per cent concentration of Ringer's solution, was used 200,000 times by the Wehrmacht, with good results. The present opinion is that it should be used in a 3.5 per cent solution, since a 3 per cent solution has about the same colloidal osmotic pressure as plasma. At some time in the future this preparation will be made available in this country. At present there is a substitute which is available under the name of "dextran." It is a polysaccharide of large molecular weight made up in 6 per cent solution. It also can be used in supportive therapy, and it will stay in the circulation for periods long enough to satisfy surgical needs. A preparation called "plasmoid," made of osseous gelatin, has been used and will be available. It, too, gives results similar to those already mentioned. As this problem is given more widespread attention than that accorded it now, I feel confident that such substitutes will make it possible to treat patients whose condition is such that they do not necessarily require blood. If a patient does require blood, use of such substitutes may make it unnecessary to administer as large quantities of blood as are needed now. That is, it may become possible to use these substitutes to supplement the use of blood. I feel that this may be very true in the treatment of patients with burns, for example. In such an event I think it is important to maintain a volume

of circulating fluid; it may be important for this circulating fluid to escape less rapidly from the blood stream than does serum.

As the anesthesiologist improves his knowledge of roentgenology he no doubt will be able to expedite diagnoses at night and in emergencies, such as in routine work in connection with immediate pulmonary complications that develop. In almost every institution technicians are available for the making of roentgenograms, but someone to interpret them is not always available. This phase of activity on the part of anesthesiologists will be developed, I think, by the various training centers, so that the anesthesiologist of the future will be able to recognize roentgenologically at least the common complications.

There is a field, however, in which the anesthesiologist of the future should be expected to be of real service, and that is in the control of pain and in the establishment of diagnostic and therapeutic blocks. At the moment, I am convinced that it is logical for the anesthesiologist to be the person to make these injections. He has five important concerns in the technic of injection, but first he must have an adequate consultation with the patient, he must become acquainted with the patient and he must explain to the patient what he plans to do. He should endeavor to make the patient understand that the procedure is in the nature of a test, and that if the information obtained thereby indicates treatments, such treatment may consist of physiotherapy, roentgen therapy, injection of solutions or even of alcohol, or section of a nerve, cordotomy, prefrontal lobotomy, or whatever may seem to be indicated under the circumstances.

In the ultimate, the anesthesiologist of the future will be a member of what can be considered a team for the treatment of pain. He will not be depriving some physician or physicians of patients but rather, will be a consultant in the given case. So far as therapy by injection is concerned, there is a tendency for those who have not followed this problem closely to predicate their opinion and prognosis on the degree of relief from pain the patient obtains from an injection. There is much more to it than this.

To return to the five primary concerns of the anesthesiologist in the technic of injection: first, the anesthesiologist must decide the question of the patient's tolerance of pain on the basis of his reaction to the needle punctures. Second, he must be sure that the needle is properly located, near or on the nerve trunk. This is done by roentgenograms and as a rule requires at least two views for the anesthesiologist to be certain that the needle is properly placed. Third, he must know whether paresthesia produced by material that has been properly placed reproduces the old pain or causes a new pain. Fourth, he must be aware that when some solution such as dolamin (which is three fourths of 1 per cent ammonium sulfate and an equal quantity of benzyl alcohol) is irritating

when it is injected, the paresthesia will be reproduced from 10 minutes to $1\frac{1}{2}$ hours or longer, as a result of the injection. Fifth, he should recognize that if relief from pain is obtained for a long period, the results are more encouraging than if the relief persists for a short period, namely, a few hours as compared to a few days or weeks.

Knowledge of pain pathways is not yet complete. I expect that in the future necessary information will be obtained to make it possible to recognize over how many pathways pain can travel. At the moment a particular problem is pain arising from lesions in the pancreas. It would seem that some of this pain, at least, passes over the splanchnic nerves and that perhaps some of it passes over the somatic thoracic nerves. Destruction of one pain pathway may temporarily block pain, but it may be that another pain pathway can become established.

SUMMARY AND CONCLUSIONS

The anesthesiologist of today is prepared to collaborate with the surgeon, the obstetrician, the dentist and all members of the hospital staff in connection with their problems relating to the care of the patient.

Many questions of prime concern to present-day anesthesiologists may be answered in the not-too-distant future. An attempt has been made herein to provide illustrations of what may be expected of the anesthesiologist of the future. A few practical examples have dealt with the work of the anesthesiologist of today as well as the anesthesiologist of the future.

DIFFERENTIAL DIAGNOSIS OF SARCOMA OF THE STOMACH

Report of 4 Cases

CLAUDE F. DIXON AND ELWYN S. SHONYO

The subject of gastric malignancy has received progressively more attention in the medical literature in recent years than previously and, on the basis of data obtained from collected statistics, attempts have been made to distinguish sarcomas from carcinomas clinically without marked success. Such a differential diagnosis is important because a large sarcomatous lesion is usually more amenable to surgical treatment or roentgen therapy or both than is a carcinoma of comparable size. Unless the surgeon suspects a sarcoma, the lesion may erroneously be termed "inoperable" on the assumption that it is a carcinoma.

Sarcomas of the stomach constitute about 1 per cent of gastric malignant lesions^{1, 2, 5, 6} and have been classified by Madding and Walters^{1, 2} as follows: Lymphosarcoma, 62 per cent, of which 30 per cent are of the reticulum-cell type and 32 per cent are of the small round-cell type; fibrosarcoma, 13 per cent; leiomyosarcoma, 11 per cent; Hodgkin's type, 8 per cent; and mixed group, 6 per cent.

DIFFERENTIAL DIAGNOSIS

Epigastric pain has been reported previously as a sign of gastric sarcoma.^{1, 2, 8, 9, 11} It is one of the most constant symptoms. However, we find that it is usually not of the ulcer type as has been reported. There may be, and there often is, a history which is typical of that of an old ulcer but if the symptoms are carefully evaluated, one will usually find evidence of a more recent superimposed pain which is more severe and persistent in type and which responds poorly to the usual antacid therapy.

The site of the lesion is usually away from the pylorus.^{4, 10} In descending order of frequency, the parts involved are the lesser curvature, posterior wall, pylorus and greater curvature.⁹ Obstructive type of vomiting is therefore late as compared with that of the average carcinoma. The lesion may grow to such size that it can be easily palpated through the abdominal wall,¹ which, in the absence of obstruction, may be a diagnostic point.

Roentgenographic^{2, 11} and gastroscopic examinations¹⁰ reveal the presence of malignant lesions only but are of little value in determining the nature of the lesions.

The general appearance of the patient is another factor to be con-

sidered. The hemoglobin content of the blood is usually not greatly reduced in a case of sarcoma and the patient does not present an appearance of emaciation and pallor as is commonly found with carcinoma. Age and sex are factors statistically, but are of little diagnostic value in the individual case. Sarcoma of the stomach usually occurs between the ages of 40 and 50 years, or roughly 10 years earlier than does sarcoma in general.^{2, 4, 9, 11} A sex ratio ranging from 2 to 6 males to 1 female has been reported.^{2, 10} Of the 24 patients operated upon at the clinic from 1943 through 1947, 16 were male and 8 were female, a ratio of 2:1, which is comparable to the sex ratio of carcinoma.

TREATMENT AND PROGNOSIS

Today, as when Balfour wrote eighteen years ago, subtotal gastrectomy should be advised in all but the most advanced cases. Most authors state that roentgen therapy following surgical treatment is generally of value,^{2, 7, 11} especially if the lesion is a lymphosarcoma. Our experience has led to the conclusion that roentgen therapy has proved most effective against the small round-cell type, somewhat less effective against the reticulum-cell type, and least effective against leiomyosarcoma.

REPORT OF CASES

CASE 1—This patient aged 57 years entered the clinic December 30, 1947. He had had mild intermittent indigestion for ten years but there had been no periods of definite exacerbation and remission. His symptoms had always been relieved by food and alkali. One year prior to admission he began to experience a new type of epigastric pain which was severe, which was only partially relieved by the usual antacid measures and rest, and which was usually brought on by rough-riding vehicles. Intermittent melena appeared three months prior to admission.

The roentgenogram disclosed a large penetrating gastric ulcer off the lesser curvature. The hemoglobin content of the blood was 7.9 gm per 100 cc. The erythrocytes numbered 3,040,000 per cubic millimeter of blood and the leukocytes numbered 8,600. The value for total gastric acidity was 60, and for free acidity 40 (Töpfer's method).

On January 9, 1948, a subtotal gastrectomy of the posterior Polya type was performed. Beginning 2 cm above the pyloric ring on the anterior wall of the stomach, there was an ulcerative reticulum-cell lymphoblastoma, type B (Dukes), that measured 8 by 7 by 2 cm. There was involvement of the peritoneum but the lymph nodes presented only evidence of inflammation.

The patient returned for a course of deep roentgen therapy in March, 1948. He was living and well when last contacted.

In case 1 the presence of sarcoma was suspected by one of us (C. F. D.) preoperatively.

CASE 2.—This patient aged 52 entered the clinic in March, 1947. He said that he had "gas on the stomach" during the previous twenty-five years. In the fall of 1946, he began to have abdominal gas pains after meals. These pains lasted one to two hours and were relieved upon belching. During the winter, night pains and cramps developed; these were relieved with milk and soda at first. Then epigastric pain began to appear after meals during the day, with extension into the right side of the thorax. Soda became progressively less effective in producing relief. By April, 1947, he had noticed progressive anorexia, fullness in the stomach, and a loss of 60 pounds (27.2 kg.), but no dysphagia.

The roentgenogram revealed "carcinoma of the middle third of the stomach." The hemoglobin measured 13.2 gm. and the erythrocytes numbered 4,150,000. There was no free gastric acidity and the value for total acidity was 12.

Total gastrectomy was performed on June 4, 1947. A reticulum-cell sarcoma (grade 4, Broders; type B, Dukes) measuring 15 by 15 by 1.5 cm. and involving the mucosa and submucosa was removed. Roentgen therapy was started on June 28, 1947, and a second course was started on October 22, 1947. When last contacted, the patient was living and well.

CASE 3.—This patient aged 62 years entered the clinic on December 13, 1943. He had had a duodenal ulcer, proved roentgenographically, for twenty years. He had had intermittent bouts of periumbilical pain that came on two to two and a half hours after meals and was relieved by food and alkali. Two years prior to admission he began to notice an increase in indigestion and a more marked, dull, epigastric pain that was localized higher in the abdomen than the previous pain and that was poorly relieved by food and alkali. Roentgenograms made prior to admission to the clinic revealed a large ulcer on the lesser curvature of the stomach which resolved only slightly after rest, modified diet, and antacid therapy. On admission the value for hemoglobin was 14.1 gm. The value for free gastric acidity was 0, and for total acidity 12.

On December 21, 1943, partial gastrectomy of the posterior Polya type was performed. On the lesser curvature 8 cm. above the pylorus there was a lymphosarcoma (grade 4, Broders; type B, Dukes) 4 by 4 cm. in diameter. The peritoneum was involved but only inflammatory changes were present in the lymph nodes. The patient received two courses of deep roentgen therapy in February and April, 1944. In February, 1948, he was living and in good health.

CASE 4.—This patient aged 54 years entered the clinic October 2, 1917 with a history of intermittent mild epigastric pain which was relieved by food and soda. This pain had continued for three years and then, during the fourth year it had become moderately severe and had occurred almost daily about three hours after meals and at about 10 p.m. The patient obtained only partial relief from food and soda.

Roentgenograms disclosed a lesion at the outlet of the stomach and grade 2 retention (on a basis of 1 to 4). The value for hemoglobin was 70 per cent. The value for free gastric acidity was 20, and for total acidity, 40.

Partial gastric resection of the anterior Polya type was performed by C. H. Mayo. A lymphosarcoma was removed. The patient received no roentgen therapy. In October, 1942, twenty-five years later, the patient had a recurrence of

"stomach trouble" and was operated upon elsewhere in January, 1943. He died one month later. The diagnosis at operation was again lymphosarcoma.

Case 4 is interesting because an interval of twenty-five years elapsed between initial treatment and the reappearance of either the same lesion or a similar one. The question naturally arises as to whether or not the reappearance of a sarcoma of the stomach after surgical excision or roentgen therapy or both represents a recurrent lesion or a second primary lesion. As evidence that it might be a second primary lesion, the pathologic reports on the 24 patients with sarcoma of the stomach who were operated upon at the clinic from 1913 through 1947 revealed that the surgical specimens from 7 patients (29 per cent) presented multiple (multicentric and synchronous) lesions. These lesions occurred simultaneously, and one might reasonably assume that such multiple lesions could occur in a serial (multicentric and metachronous) order as well. The fact that twenty-five years elapsed between the first and second appearances of sarcoma in case 4 also places suspicion upon any assumption that the second lesion represented merely a recurrence of the original tumor.

SUMMARY AND CONCLUSIONS

Twenty-four patients with sarcoma of the stomach were operated upon at the Mayo Clinic during the five-year period, 1913 through 1947. Four cases are reported. In 1 case, either a local recurrence or a new similar lesion developed twenty-five years after gastric resection.

The differential diagnosis of sarcoma of the stomach can not be made in a clear-cut manner because no known signs or symptoms are pathognomonic of this type of tumor. However, on the basis of the data on reported cases in the literature and data on our own cases, it would seem that in the presence of a malignant gastric lesion proved by roentgenogram, a history principally of epigastric pain that is not associated with obstruction, that is not appreciably relieved under management for ulcer, and that is associated with a minimum of anemia and malnutrition may be considered presumptive evidence of gastric sarcoma. Although this symptom complex does not necessarily preclude the presence of gastric carcinoma, we have found that the diagnostic acumen of the surgeon can be increased by keeping it in mind.

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ANNULAR RECTAL STRICTURE RESULTING FROM COMPLETE OR INCOMPLETE INTERNAL FISTULA IN ANO

NEWTON D. SMITH AND JOHN R. HILL.

The etiology and the treatment of rectal stricture has proved always to be a subject of interest to the diagnostician and surgeon. Our interest in a limited group of patients with this condition was aroused chiefly because of the rather extensive surgical procedures that were frequently employed and also because of the satisfactory results. The generalized discussion of lymphopathia venereum and the recognition of the relationship of this infection to rectal stricture have had a tendency to overshadow the importance of other etiologic diseases and factors. Our group of 12 cases illustrates an interesting diagnostic and surgical problem.

In 1943 F. C. Yeomans, while discussing his observations based on 119 cases of stricture that he had encountered, stated, "Rarely blind internal, but more frequently blind external fistula by encircling infiltration causes stenosis of the bowel at the ano-rectal line." He further cited 9 such cases; in 5 the lesion was in the anal canal, in 1 it was within 5 cm. of the anus, in 2 it was 6 to 10 cm. above the anus, and in 1 it was more than 10 cm. above the anus. The Frei test gave positive results in 2 of these cases. In his group there were 6 males and 3 females. The following discussion will reveal some variation between the statistical data on Yeomans' cases and the statistical data on our cases, but this probably results because of the small groups of patients rather than because of factual variation.

In selecting this group of cases we reviewed the records of 400 cases of stricture resulting from a variety of etiologic agents or causes. Table 1 illustrates the etiologic factors and proportionate representation. It will be noted that cases in which stricture resulted from complete or incomplete internal fistula represent 3 per cent of the total group.

We have abstracted those facts which seem to be important for the understanding of these cases. In this group of 12 cases, there were 4 men and 8 women, and all were white except 1 woman. Six of the patients underwent a Frei test with suitable control, and all gave negative results. In 1 woman the tissue removed at the time of operation revealed the presence of tuberculosis. There is an interesting variation in the ages of the patients, which is probably of no significance; the ages of the 8 women varied from 28 to 46 years, but the 4 men were from 50 to 55 years of age. Each of the patients had a complete physical examination, and in none of them was any abnormality observed that could be related to the stricture.

The preoperative diagnosis of rectal stricture resulting from a complete or incomplete internal fistula was made in only 5 cases, and the possible etiologic relationship was suspected in 2 more cases. In reviewing these cases we were impressed by the fact that because of the presence of the stricture, because of anorectal tenderness, and because of the patient's apprehension resulting probably from previous anorectal operations, the diagnosis could not be made accurately until the patient could be examined while he was under anesthesia. In several of the cases it was necessary to cut through the wall of the stricture in order to obtain satisfactory exposure, and the primary incision disclosed the presence of the fistula. The underlying pathologic process in 5 of the patients was ob-

TABLE 1
NONMALIGNANT RECTAL STRICTURE.

Cause of Stricture	Patients
Chronic ulcerative colitis	178
Lymphogranuloma inguinale	61
Following surgical procedures for rectal carcinoma	22
Following radium treatment of carcinoma of cervix	21
Following fulguration or radium, or both, for treatment of rectal carcinoma	10
Complete or incomplete internal fistula	12
Following injection treatment for hemorrhoids	7
Inflammatory extrarectal mass	7
Tuberculosis	6*
Endometriosis	3
Amebiasis	2
Diverticulitis	2
Traumatic (enema burn)	2
Unclassified	61
Total	400

* Tuberculosis was actually present in 7 patients, 1 patient is listed in the group, "Complete or incomplete internal fistula."

scured by previous surgical procedures or the injection treatment for hemorrhoids. Eight of the patients in this group had been treated surgically elsewhere without obtaining satisfactory relief. The failures seem to result from erroneous diagnosis or incomplete exposure of all of the fistulous tracts. The latter could be understood when the complexity of some of the fistulas was discovered.

In 6 of the cases the requisite surgical procedure to produce a cure was very extensive. It would be necessary to reproduce herein all of the surgeon's notes at the completion of the operation if all of the facts were to be disclosed, but it may suffice to enumerate these facts. In 3 instances there were large abscess cavities having thick fibrous walls, in addition to the fistulous tracts. In 4 of the cases in women, there were tracts extending externally into the labia and perineum, and in 2 of the 4 cases into the vagina. In 3 of the 4 cases the fistula involved the right and left

sides of the anus and rectum and required remarkable surgical procedures to expose all of the tracts and still to preserve as much tissue as possible. Briefly, in 6 of the cases the process required extensive surgical procedures, in 3 it required a more extensive procedure than would be necessary for a routine internal fistulectomy, and in 3 the surgical procedure was not unusual.

The primary opening was in the posterior midline at the level of the dentate margin in 9 of the 12 cases. In 2 of the women the primary opening was located in the dentate margin in the anterior midline, and in another woman the primary opening was on the left anterior quadrant of the anus at the level of the dentate margin.

It is interesting to observe that all but 1 of the patients had good results, and in this 1 patient there may be further improvement. In all instances except the 1 mentioned, the stricture cleared up reasonably soon after all of the fistulous tracts and abscess cavities had been uncovered and ample drainage had been insured. In the 1 instance the abscess and its numerous ramifications had destroyed so much tissue that the stricture was not attacked as radically as usual because the patient had moderately satisfactory control of the bowel evacuations with the stricture present but probably would have had no control had the stricture been cured. In 2 other patients, poor control resulted, but in 1 of these, the problem of control was troublesome only when diarrhea occurred. In these 3 cases the amount of destruction of tissue by the inflammatory process was excessive, causing poor control in 2 of them before any surgical procedure was attempted. Several other patients mentioned that they had difficulty in controlling the evacuation of stool prior to the surgical effort and remarked that when the stricture had been cured, this difficulty subsided satisfactorily.

In conclusion, we have called attention to this group of cases because they produce interesting and often difficult diagnostic problems. The surgical problem is a complex one, often mechanically difficult of accomplishment, but the results justify the effort. Unlike most other rectal strictures, these can be cured when correctly diagnosed and properly treated. Occasionally, rectal incontinence may result, but ordinarily rectal incontinence resulting from the presence of a rectal stricture caused by a complete or incomplete internal fistula may be relieved when the stricture is cured.

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SURGICAL CONDITIONS COINCIDENT WITH PREGNANCY

ROBERT B. WILSON AND ROBERT D. MUSSEY

Surgical conditions are of particular interest, for several important reasons, when they complicate pregnancy. First, accurate diagnosis is often more difficult because of the size of the pregnant uterus and because the surgical condition must be distinguished from a number of conditions which are peculiar to pregnancy alone. Second, the surgical condition may progress more rapidly in pregnancy. Finally, institution of the proper treatment may precipitate abortion or premature labor.

It is well known that any disease or condition which is commonly treated by a surgical procedure may occur in a pregnant woman. It is usually wise to defer surgical treatment of an elective nature, however, unless it is believed that the disease or condition under consideration will exert an adverse effect on the life and health of the mother or on the progress of gestation and subsequent parturition.

On the other hand, in the presence of some surgical conditions, such as cholelithiasis or questionable appendicitis, in which the clinical findings suggest that symptoms are likely to become acute before the termination of pregnancy, it may be advisable to employ surgical therapy early in gestation.

NATURE OF PRESENT STUDY

In 1946 and 1947 there were 2,637 deliveries on our obstetric service in the Clinic. During these same years fifty-five surgical procedures were performed on pregnant women. This incidence of surgical operations of 2.08 per cent does not include the numerous surgical procedures which are peculiar to pregnancy, such as dilatation and curettage for incomplete abortion, therapeutic abortion, ectopic gestation, cesarean section and the like, which will not be considered in this paper. The afore-mentioned incidence of 2.08 per cent probably is higher than would be expected ordinarily, because the figure includes a number of patients who were referred to the Clinic for surgical therapy of a specific condition, and whose pregnancy was not the primary reason for their consultation.

The specific surgical procedures performed do not warrant tabulation. It is interesting to observe, however, that in the 55 instances of surgical therapy there were 22 different conditions. Craniotomy was carried out once for an astrocytoma; a parotid gland was removed because of the presence of an adenocarcinoma and a carcinoma of the bowel was excised. Most of the surgical procedures were for more common conditions such as

appendectomy for acute appendicitis and oophorectomy for various types of ovarian cysts

SPECIFIC SURGICAL CONDITIONS

Inflammatory Abdominal Conditions.—During pregnancy, as would be expected, acute appendicitis is the most common cause of a peritoneal insult which requires surgical intervention. Nevertheless, such conditions as intestinal obstruction and acute cholecystitis are often encountered.

The difficulties inherent in the making of an accurate diagnosis in these conditions are made even greater by intra-uterine pregnancy. Not only must noninflammatory conditions be excluded, but in addition, ectopic pregnancy, pyelitis and the various accidents occurring to ovarian cysts, which are so commonly seen, must be ruled out. Awareness of the displacement of the abdominal viscera by the enlarged uterus is very necessary for accurate diagnosis. This is of particular importance in the diagnosis of appendicitis, in which the localizing signs and symptoms may well be situated in the right upper abdominal quadrant or posteriorly, rather than in the right lower quadrant.

When it is certain that an acute inflammatory process is present, immediate surgical exploration of the abdomen generally is necessary. This is particularly true in pregnancy because the size of the uterus interferes with the effectiveness of the intra-abdominal localizing defenses. Because the intestines and the omentum are unable to wall off the area surrounding a ruptured viscus, the peritonitis which follows in such instances is more fulminating and diffuse than it would be otherwise.

Even though surgical intervention is accomplished without delay, cellulitis or generalized peritonitis may occur. This is, of course, a serious matter. However, with the intelligent use of modern chemotherapeutic and antibiotic agents, most of the conditions commonly encountered should respond to treatment. If, for example, at the time of surgical intervention a ruptured appendix with abscess formation or peritonitis is encountered, intraperitoneal chemotherapy should be employed. It is recommended that 5 to 10 gm. of sulfathiazole be placed in the peritoneal cavity at the time of institution of drainage or removal of the appendix. Although there is no contraindication to the intraperitoneal use of 1 gm. of streptomycin or 1,000,000 units of penicillin or a combination of both, it should be pointed out that both of these antibiotic agents leave the peritoneal cavity rather rapidly.

On the other hand, sulfathiazole often will remain in the peritoneal cavity as long as four or five days. Sulfathiazole is polyvalent, it is relatively nontoxic, is unlikely to cause adhesions and is, therefore, still the drug of choice for intraperitoneal use.

If surgical intervention is impossible, is deemed unwise, or is under-

taken after the onset of peritonitis, the systemic use of massive doses of antibiotics is the procedure of choice. It is recommended, therefore, that the patient receive, in addition to the usual supportive measures, 1,000,000 units of penicillin by the systemic route every twenty-four hours. On occasion, 1 to 1.8 gm. of streptomycin may be administered, together with the large dose of penicillin. If the infection is refractory or resistant to treatment with penicillin or streptomycin or a combination of both, the use of aureomycin would then be justified. If the patient is able to take medication orally, the recommended daily dose of aureomycin would be 750 to 1,000 mg. every six hours. If for any reason the patient is unable to take the antibiotic by mouth, it may be administered intravenously. For intravenous aureomycin therapy it is recommended that 500 mg. in 300 cc. of distilled water or solution of sodium chloride be given rather rapidly every twelve hours, until the patient's general condition will permit a change of method of administration to the oral route.

Aureomycin is somewhat irritating and its continued administration by the intravenous route would be likely to cause phlebitis. However, it should rarely be necessary to give this antibiotic intravenously more than one or two times, in which case severe phlebitis would not be likely to occur.

Noninflammatory Pelvic-Abdominal Conditions.—Such conditions commonly resolve themselves into one of three things: an ovarian cyst, a fibromyoma or cholelithiasis. The diagnosis of any of these conditions generally is obvious after the usual history has been taken and physical examination carried out. Management of such conditions, however, often requires considerable judgment.

The diagnosis of cholecystic disease, especially early in pregnancy, may be missed because of misinterpretation of symptoms. The physician is much more likely to attribute upper abdominal discomfort, various types of indigestion and an intolerance to certain foods to the nausea and vomiting syndrome of pregnancy rather than to cholecystic disease. This difficulty is further enhanced if the patient gives no history of jaundice or colic. Once the diagnosis has been made, surgical treatment should be deferred unless the patient has repeated colic or is jaundiced, or unless acute cholecystitis develops.

Uterine fibromyomas frequently are found in the pregnant woman. Fortunately, these tumors as a rule are not too large and are located in a position which does not interfere with the normal progress of gestation or with subsequent parturition. Red degeneration in these fibromyomas is common and, because of local peritonitis, is often associated with great pain. But this degenerative process usually is self-limiting and it is therefore possible to treat the patient by means of sedation until the pain subsides.

eight weeks Hemoglobin amounted to 10.2 gm per 100 cc. of blood; erythrocytes numbered 4,170,000 and leukocytes 10,200 per cubic millimeter of blood; result of the Kline test was negative, that of the Friedman test was positive; the blood group was O, the Rh factor was positive. Consultation was obtained. All concerned felt that it was impossible to state whether the tumor was uterine or ovarian in origin, and all advised that the abdomen be surgically explored. On April 20, 1948, exploration revealed the uterus to be huge—it extended to the liver and filled the entire abdomen. The cervix was pushed above the symphysis pubis and the fetus was pushed back into the pelvis. Multiple fibroids were present, the largest of which was removed. The uterus was reconstructed. This fibromyoma was 20 by 18 by 15 cm., and weighed 2,100 gm. The patient's condition was satisfactory until 10.30 p.m. on April 22, when sudden and profuse vaginal bleeding occurred and was followed almost immediately by peripheral vascular collapse. The bleeding was so profuse that it was necessary to perform cesarean section and hysterectomy. The infant was small and survived but one hour. At the time of this emergency operation, it was determined that the bleeding was due to premature separation of the placenta. The patient's convalescence was uneventful.

The case just reported illustrates the difficulties that can arise even in the diagnosis of fibromyomas. We were misled in this case by the soft consistency of the tumor and by the position of the cervix behind the symphysis pubis—both findings being more commonly seen in the presence of large ovarian cysts. This case also illustrates how a serious postoperative complication can occur, namely, premature separation of the placenta. In retrospect, it is possible that this patient could have been observed until our hand was forced, at which time cesarean section and other necessary surgical procedures could have been performed. Had this been done, a living infant might have been obtained.

CASE 2—A woman 32 years old was admitted to the Clinic on June 4, 1948. She had had two children and at this time was in her third pregnancy. The last menstrual period had occurred on January 2, 1948, the expected date of confinement was October 9, 1948. The patient gave a history of symptoms typical of exophthalmic goiter dating back to 1939. Her local physician had prescribed Lugol's solution, 10 drops to be taken three times a day. She had taken this solution intermittently when she "felt nervous or lost weight." Shortly before her admission she had seen her local physician, who told her that her thyroid gland was active and referred her to the Clinic for care.

Examination revealed an extremely agitated woman who had exophthalmos, grade 2+ (on the basis of 1 to 4, in which 1 represents the least, and 4 the most, severe condition). A symmetrical goiter was present, each lobe of the gland being about 7 by 5 cm. and with a noticeable bruit. The heart was bounding and rapid, the enlargement of the uterus corresponded to that at the seven month of gestation, the fetal heart tones were rapid but otherwise normal. Albuminuria of grade 2 was present, otherwise the urine was normal; hemoglobin amounted to 10.4 gm per 100 cc. of blood, erythrocytes numbered 4,420,000 and leukocytes

9,600 per cubic millimeter of blood; the basal metabolic rate was +100, the blood was group A; the Rh factor was positive. The patient was hospitalized. On June 7, a sterile vaginal examination was done because of vaginal bleeding, but placenta previa was not found. Lugol's solution was administered. In addition to all the classical signs of severe hyperthyroidism, symptoms referable to the upper part of the respiratory tract developed. Examination of the thorax, including the making of a roentgenogram revealed marked cardiac enlargement, bilateral passive pulmonary congestion and pneumonia in the lower lobe of the right lung.

Labor began spontaneously on June 8, and after two hours a 1,450 gram infant was delivered. The patient's condition immediately became more critical, with a thyroid crisis, acute congestive heart failure and pneumonia. Treatment consisted of the administration of oxygen, morphine, digitalis, Lugol's solution, procaine penicillin, regular penicillin and streptomycin. The patient's temperature varied between 100.8° and 102.4° F, the pulse from 110 to 130, respirations from 35 to 60, until June 13, when, for the first time, improvement began. This improvement was continuous. The patient was dismissed from the hospital on June 28, 1948. A program consisting of the taking of 100 mg. of propylthiouracil three times a day and 10 drops of Lugol's solution three times a day and a high-calorie, high-vitamin, salt-poor diet, was prescribed for her. This therapy was continued until August, 1948, at which time the basal metabolic rate was +17. Subtotal thyroidectomy was then done. Letters received from the patient indicate that, at the time of this report, both she and the infant were well.

In some respects it might be said that this patient had neglected her own condition; but it is also true that she was given access to iodine without continuous observation. Delivery of the infant prior to the control of the patient's severe symptoms almost caused her death. It should hardly be necessary to point out that hyperthyroidism should not be allowed to go untreated and that delivery of an infant from a patient with uncontrolled symptoms may precipitate a thyroid crisis.

CASE 3—A white woman 28 years old came to the Clinic because of her pregnancy in December, 1946. She stated that she had been pregnant twice previously; the first pregnancy had terminated at the eighth month of gestation with placenta previa and death of the infant at the age of four weeks; the second had ended with spontaneous abortion during the sixth week of gestation. The last menstrual period had occurred November 7, 1946; the estimated date of confinement was August 14, 1947.

Progesterone and stilbestrol were given as antiabortion therapy. Slight vaginal bleeding occurred rather frequently until January 22, 1947, when severe lower abdominal pain suddenly occurred which required hospitalization. This pain and the results of examination of the pelvis were very suggestive of an ectopic gestation.

Hemoglobin amounted to 12.4 gm. per 100 cc. of blood; erythrocytes numbered 3,980,000 and leukocytes, 16,400 per cubic millimeter of blood; a specimen of

urine obtained by catheter was normal, the blood group was A; the Rh factor was positive. At operation the patient was found to have fairly extensive endometriosis and an intra-uterine pregnancy. Acute symptoms were due to a ruptured chocolate cyst on the left. Both ovaries contained chocolate cysts and were bound down to the posterior wall of the uterus. The ruptured chocolate cyst and another chocolate cyst were freed up from the cul-de-sac, the second chocolate cyst was opened and its contents evacuated. The walls of the cysts were resutured and the mobilized ovaries were sutured to the round ligaments. Antiabortion therapy was continued, the pregnancy progressing uneventfully until June 18, 1947, at which time the membranes ruptured spontaneously. This was the thirty-second week of gestation. Labor ensued ten days later. A 1,700 gm infant was delivered spontaneously. This infant lived and has done well.

The foregoing was a rather unusual case of a ruptured endometrial cyst. Although endometriosis often is associated with infertility, a pregnant patient who has endometriosis is sometimes seen. Instances of acute peritoneal irritation due to a ruptured endometrial cyst are becoming more common in our experience. The difficulties of making an accurate diagnosis are self-evident, as is the importance of conservative surgical treatment.

CASE 4.—A white woman 18 years old was seen for her first prenatal visit on February 8, 1946. The last menstrual period had occurred on August 7, 1945. The expected date of confinement was May 14, 1946. Physical examination revealed an intra-uterine gestation of six months' duration and a right ovarian tumor. Roentgenologic examination of the abdomen revealed a dermoid cyst in the right side of the pelvis. Because it was felt that the tumor would obstruct the birth canal, salpingo-oophorectomy was performed on the right, on February 25, 1946. The dermoid tumor was 12 by 10 by 8 cm, and weighed 290 gm. The postoperative course was uneventful. However, labor began seventeen days postoperatively. A living infant weighing 2,010 gm was delivered normally. The infant was vigorous and lived.

The patient returned on January 20, 1947, again pregnant. The last menstrual period had occurred on October 12, 1946. The expected date of confinement was July 19, 1947. Another ovarian tumor was found in the pelvis, this tumor, because of the previous history, was presumed to be a dermoid cyst involving the left ovary. The patient was treated expectantly and a normal infant was delivered at term on July 11, 1947.

On September 23, 1947, a portion of the left ovary was excised which contained a dermoid cyst 8 by 7 by 5 cm, weighing 210 gm. At the time of this operation it was felt that enough ovarian tissue remained for normal function. That ovarian function was present was proved when the patient presented herself in November, 1948, with a left ectopic pregnancy which required left salpingectomy.

In the instance of this patient's first pregnancy, the dermoid cyst was removed because it was obstructing the birth canal. In the second pregnancy, it was possible to observe the patient and to allow the pregnancy to progress and end normally. In such cases as this the surgeon should endeavor to dissect the dermoid cyst away from the ovary and leave functioning ovarian tissue when this is technically possible.

SUMMARY AND COMMENT

Essential observations concerning the more common surgical conditions occurring coincidentally with pregnancy have been presented. Surgical treatment is indicated in those conditions which may immediately or remotely endanger the life of the mother or which may later affect the normal progress of gestation or subsequent parturition. Surgical treatment of an elective nature usually is wisely deferred until the pregnancy is terminated.



REACTIONS TO TRANSFUSION DURING OPERATION

THOMAS H. SELDON

During the last few years, blood transfusion has become an important therapeutic procedure, for both medical and surgical patients. During this time the interest in, and use of, this method of treatment has gained its greatest momentum.

No matter how well a transfusion service has been organized and how much care is taken to overcome human error, one must accept a certain percentage of untoward reactions following blood transfusion.

It is not within the province of this paper to go into the laboratory side of this problem except to say that the laboratory work that is necessary to carry out a successful transfusion service is of utmost importance. Testing serums of adequate strength and laboratory technicians skilled enough in their specialty to read accurately the tests they perform are some of the first essentials to carrying out a successful procedure.

When an untoward reaction does occur, it is of the highest importance to try to distinguish it from the underlying disease of that patient. While the patient is undergoing a surgical procedure, it is rather difficult to recognize an untoward reaction as it is so often hidden by the effects of the anesthetic procedure. In spite of this anesthetic and surgical procedure, if one is alert to the possibilities of reactions, at times one can suspect that something untoward is occurring if a reaction does take place while the patient is under general anesthesia and almost certainly so if the patient is under the effects of a local or spinal anesthetic agent.

One is not justified in calling any and all untoward happenings due to transfusion simply by the word "reactions." The seriousness of the situation varies according to the type of the reaction. Therefore, one should try to classify the type, as almost invariably the subsequent treatment follows different lines according to the type of reaction.

It is the practice in the institution with which I am associated to classify all untoward happenings into one of five categories; namely, pyrogenic, allergic, circulatory, hemolytic and the so-called undetermined happenings. This last category is a hodgepodge into which we place any untoward happening that accompanies the administration of blood when we are not sure if the blood should or should not be blamed for the happening.

Unfortunately, many persons are misinformed in that they believe transfusion reactions do not occur when a patient is under the effects of a

general anesthetic agent. This is erroneous, as any type of reaction may be experienced by the patient who is under the effects of an anesthetic agent.

PYROGENIC REACTIONS

A pyrogenic reaction usually exhibits itself by a rise of temperature of 1° to 4° F. appearing during or immediately after the transfusion. The temperature rise usually lasts one to eight hours, and unless something intervenes the temperature returns to the level that existed before the transfusion. A simple rise of the temperature is usually of no great significance as the patient will have derived the usual benefit he is expected to obtain from the transfusion. It is true that it is sometimes difficult to distinguish this rise from the expected postoperative rise of temperature. However, ordinarily one should expect a greater rise of temperature if a pyrogenic reaction does occur. In the event one gets this greater than expected rise of temperature and the patient's condition otherwise is satisfactory, then it may be suspected that this rise is due to the effects of the transfusion. As far as a simple pyrogenic reaction is concerned, the patient usually is not greatly disturbed. If the patient is awake, some sedative such as codeine or morphine may be given. The rise in temperature is frequently preceded by a sudden chill and even marked shivering of the patient. This shivering may be seen occasionally when a patient is lightly anesthetized. For this chilling and shaking, heat is applied in the form of hot-water bottles, electric blanket or other warming devices.

If this reaction is severe enough it may be difficult to distinguish it at first from the beginning of a hemolytic reaction. However, a hemolytic reaction usually is accompanied by other more severe symptoms such as pain in the lumbar region, anxious expression of the face, cold, clammy skin and other symptoms of shock. If one suspects a hemolytic reaction, 5 cc. of blood is withdrawn into a tube containing 0.5 cc. of 6 per cent solution of ammonium oxalate and 4 per cent solution of potassium oxalate. After centrifuging, the supernatant plasma is examined for free hemoglobin. The patient with a pyrogenic reaction should not necessarily have free hemoglobin in the plasma, whereas the patient with a hemolytic reaction usually has considerable free hemoglobin in the serum within a few minutes of the transfusion reaction.

If blood is still being administered at the time of the occurrence of the reaction, its administration should be discontinued till the patient's general condition is evaluated and the type of reaction is determined. By at least temporarily discontinuing the blood the patient is not subjected to a greater insult in case the reaction is hemolytic in nature instead of pyrogenic.

ALLERGIC REACTIONS

Allergic reactions usually manifest themselves by the sudden appearance of urticaria, hives or even angioneurotic edema. This reaction may be accompanied by lumbar pain, dizziness and headaches. Many of these symptoms may be masked, but I have seen marked urticaria, hives and even laryngeal edema with the patient under general anesthesia. The exact cause of these reactions is not entirely understood. In many instances the donor and recipient can give no history of allergic manifestations. The same donor's blood does not necessarily give an allergic reaction in all recipients. The elimination of all donors having active hay fever or asthma seems to decrease the incidence of these reactions somewhat. Occasionally donors have ingested foods to which the recipients are allergic and the recipients react by exhibiting hives or other allergic phenomena.

In the event of an allergic reaction in a patient under the effects of an anesthetic agent, epinephrine may be administered subcutaneously or intravenously if it is not otherwise contraindicated. If given at the time the allergic reaction actually occurs, the antihistaminic drugs are of relatively less benefit than if they are given before the reaction occurs. If more severe symptoms are experienced, the treatment must be symptomatic.

In the event one is forewarned about transfusing a patient having such tendencies, one should (1) use a fasting donor and (2) administer antihistaminic drugs to the patient before the transfusion. An antihistaminic drug, as well as epinephrine if indicated, may be added to the bottle of citrated blood and administered continuously with the blood.

Certain patients seem to be so sensitive that it is almost impossible to transfuse them and not get symptoms. On occasion my colleagues and I have found that one can transfuse these patients with washed erythrocytes quite successfully. However, I suggest that when these cells are resuspended in saline solution they should be transfused soon after being resuspended because if left standing in saline solution the cells will tend to deteriorate in a few hours.

In spite of the allergic reaction, one hopes to get the usual therapeutic effect. However, some allergic reactions may be severe enough to produce a laryngeal edema that necessitates more drastic treatment such as the administration of oxygen or oxygen under pressure, or maybe even a tracheotomy. I am sure that severe allergic reactions of this magnitude lower the value of the transfusion to the patient to a greater extent than does the allergic reaction that is mild in nature.

CIRCULATORY REACTIONS

Usually this type of reaction is seen in patients suffering from some chronic cardiac disease. It is due usually to the disturbance of the cardiac mechanism or pulmonary mechanism that results from overloading the circulatory system. Too rapid administration or the administration of too great a volume of fluids or blood may cause this type of reaction. It manifests itself by the appearance of right-sided heart failure, very rapid pulse, a drop of blood pressure, sweating, pulmonary edema and cyanosis. No particular difficulty in diagnosis should be encountered, as the general physical condition of the patient is almost self-explanatory. When this complication makes its appearance, inhalation of oxygen under pressure is indicated and may be essential. The withdrawal of at least the same amount of blood as was administered is indicated. If this type of reaction occurs on the operating table, the patient's condition is frequently serious and may be fatal. Spontaneous recovery may occur. Other symptomatic treatment is in order.

HEMOLYTIC REACTIONS

Hemolytic reactions may be the result of various causes: (1) administration of incompatible blood, (2) administration of too high-titered group O blood to a group AB, A or B recipient, (3) administration of hemolyzed blood or (4) intragroup incompatibilities or the fact that a patient with Rh-negative blood becomes sensitive to the Rh factor and receives Rh-positive blood.

A hemolytic reaction produces agglutination and hemolysis and results in a more or less serious transfusion reaction. The reaction at times may be so mild as to go unnoticed and at other times severe enough to result in a fatal outcome within a few hours. The reaction is usually manifested by sudden lumbar pain, cold clammy skin, shock, fall of blood pressure, rapid thready pulse, dyspnea, cyanosis and air hunger. If the shock is successfully treated, the next symptom usually is the appearance of jaundice within a few hours.

If this reaction occurs on the operating table, with the patient under general anesthesia, it is recognized with greatly increased difficulty. However, it has been interesting to me that on three occasions when incompatible blood was administered accidentally to an anesthetized patient, three different surgeons made much the same remark. Each in turn complained of the increased bleeding and oozing from the operative site and no one at the time suspected that incompatible blood was being administered. The oozing and bleeding were severe enough to be very difficult if not impossible to control.

In the event that the patient exhibits these symptoms, one may notice a short time later that there is a hemorrhagic tendency as indicated by

oozing of blood from the transfusion site, gums, uterus or any skin incision recently made. If a sample of urine is obtained at this time it will usually be found to be dark in color with considerable free hemoglobin, but with few, if any, erythrocytes. A sample of blood withdrawn from the recipient at the time of the suspected reaction should show considerable free hemoglobin in the plasma.

If the reaction is so mild as to be unrecognized, it is possible that nothing will be suspected till some time later when it is discovered accidentally. However, in case of a severe reaction, an associated oliguria or anuria usually follows. The jaundice disappears in a few days. Apparently there is no simple relationship between the depth of the jaundice and the amount of the blood administered. The nitrogenous waste products start accumulating, and some hours or days later uremic symptoms make their appearance. As the uremic symptoms develop, stupor, convulsions and coma will appear unless something intervenes to improve the patient suddenly. Generalized edema and purpura may appear. If diuresis suddenly commences, the prognosis is better. However, continued anuria is indicative of a poor prognosis.

Diagnosis.—Because this is the one type of reaction to be feared most, a fuller explanation of diagnosis is in order. As previously stated, the chills and fever may be mistaken as part of a pyrogenic reaction. On the other hand the uremic state may be so late in appearing that the possibility of a transfusion reaction may have been forgotten. In this event the cause of the death may be wrongly attributed to the particular illness of the patient. Occasionally it is very difficult to decide whether the death is due to incompatible blood or acute cardiac failure.

When a reaction follows a transfusion, a sample of blood should be drawn from the recipient to determine if there has been some hemolysis. It is important that the blood be drawn into a tube containing 6 per cent solution of ammonium oxalate and 4 per cent solution of potassium oxalate. A half cubic centimeter of this mixture is adequate for 5 cc. of blood. This must be done soon after the reaction, as the free hemoglobin disappears quickly from the circulation. If the sample is taken too late a wrong sense of security may be felt by attending physicians. It has been shown in animal experimentation that the maximal hemoglobin level in the serum is reached within one minute, then rapidly falls within the next few minutes to one half of its maximal level; within four to five hours the free hemoglobin entirely disappears from the circulation.

If too old or outdated stored blood has been administered or if the blood has been improperly handled, a reaction may or may not follow. There may be free hemoglobin in the patient's serum for two or three hours, then the red color of free hemoglobin changes to the deep yellow color of bilirubinemia and fades within twenty-four to forty-eight hours. These changes may occur without any other symptoms whatever.

A sample of urine passed after the transfusion of incompatible blood is smoky red owing to the hemoglobin. Oehlecker has stated that hemoglobinuria does not occur unless at least 60 to 80 cc. of blood is hemolyzed. The coincidental presence of blood in the urine due to metrorrhagia or hematuria should cause no confusion because in these conditions numerous erythrocytes will be found and anuria is not one of the complications.

A retest of the donor's blood and the patient's blood as to grouping and Rh factor should be made, and cross matching should be done, samples of blood from the donor's bottle of preserved blood should be used for this purpose. Through human error, accidental interchange and wrong labeling of the bottle may have occurred. If fresh blood cannot be gotten from the donor, one may be able to observe that a less than average titer of *a* or *b* agglutinins in the patient's serum increases greatly in the next few days after the reaction. If the titer of either *a* or *b* agglutinins is lower than average but is higher than average a few days later, one would suspect that the patient has received some group A or B cells.

Pathologic Features.^{1, 4}—The exact mechanism responsible for the symptoms of a hemolytic reaction is not completely understood. Some of the incompatible erythrocytes are disposed of by phagocytosis, but in severe cases the donor's erythrocytes are destroyed by the circulating agglutinins. It is quite generally accepted that the renal symptoms may be caused by the fact that the hemoglobin released from the destroyed donor's cells is being deposited in the renal tubules. When the concentration of free hemoglobin in the serum exceeds a certain value, the free hemoglobin is passed out through the kidneys. The actual damage to the kidneys may be the result of (1) mechanical blockage of the tubules by crystals of hematinic acid and casts that interfere with the excretory function of the kidney. One must remember, however, that the number of actual tubules that are blocked as compared to the total number of tubules is quite small. Therefore, the author feels that simple mechanical blocking is not the only cause of the anuria. The damage to the kidneys may be due also to the fact that (2) the toxic substances produced by the hemolytic reaction may have a toxic effect on the renal parenchyma and also cause a spasm of the renal arteries that is followed by a reduced filtration pressure. It is thought possible that this arterial spasm may account for some of the lumbar pain. A very fine presentation of this whole subject has been made by Lucke. Trueta and his co-workers also have thoroughly discussed this problem.

Death following very soon after a severe transfusion reaction may be associated with multiple thrombosis. Those patients who survive a few days and have uremic symptoms experience coma and have renal changes, such as swollen edematous kidneys with degenerative changes

in the epithelium of the tubules and brownish pigmented casts in the lumens of the tubules.

Treatment.—In a suspected or proved case of hemolytic transfusion reaction, one is faced with certain definite steps. If the transfusion is still being carried out, it is stopped. An attempt must be made to support the patient during the period of shock; the administration of known compatible blood or blood plasma is in order. Alkalinization of the patient may be done by use of sodium bicarbonate or 6 molar sodium lactate. Intravenous administration of 5 per cent glucose in saline solution or in distilled water, is limited to 2,000 to 3,000 cc. daily. Careful watch is taken to prevent overloading the patient with sodium chloride. It is desirable to promote the onset of diuresis if possible. The intravenous administration of too much fluid is not desirable in trying to produce diuretic effect. Aminophylline, concentrated human serum albumin, blood plasma and so on may be tried.

In the event the patient is oliguric or anuric and the nitrogenous products in the blood are increasing, one should consider peritoneal lavage.⁵

UNDETERMINED REACTIONS

In this group go all bizarre untoward happenings which follow blood transfusion. One cannot necessarily say that the condition is not due to the transfusion, but neither can one blame the event on the illness. In such an event, one must suspect the transfusion until proof to the contrary is obtained. Treatment of this type of transfusion reaction must, of necessity, follow symptomatic lines.

CONCLUSIONS

Blood transfusions are an important part of the physician's armamentarium to treat the patient. As Crile said forty years ago, "Judiciously employed, transfusion will surely prove a valuable, often life saving, resource; injudiciously employed, it will surely become discredited."

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MIXED ADENOCARCINOMA AND FIBROMYXOSARCOMA ARISING IN FIBRO-ADENOMA OF THE BREAST

Report of Case

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Fibro-adenoma of the breast is a relatively common benign tumor which only rarely undergoes malignant change. However, during 1947 two such instances were observed at the Clinic within a period of a few weeks, in one there was evidence of adenocarcinoma alone, and in the other, a mixture of fibromyxosarcoma and adenocarcinoma. This report is concerned primarily with the latter case.

Fibro-adenomas are composed of fibrous connective tissue and epithelial elements in varying proportions. Examples with a preponderance of epithelial elements are often called "adenofibromas," one variety of which, the fetal adenofibroma, is often unjustly suspected of being malignant upon first glance through the microscope because of its rich quota of young-appearing glandular structures.

When a fibro-adenoma undergoes malignant change, the connective tissue elements are more apt to be involved, producing fibrosarcoma. Osteosarcoma¹ and chondrosarcoma² have also been described. To avoid misunderstanding it is well to recall that the so-called cystosarcoma phylloides originally described by Johannes Müller is not a sarcoma but a giant fibromyxo-adenoma.³ This tumor may occasionally, as may any fibro-adenoma, undergo malignant change.

The simultaneous combination of carcinoma and sarcoma in the same organ is extremely rare. Kerbirion and Danel first reported the condition in 1897. Saphir and Vass, who studied carcinosarcoma in general, concluded that not more than 3 or 4 of the reports of 153 cases collected from the literature could be accepted unquestionably as cases in which the lesions contained both carcinomatous and sarcomatous tissue. They emphasized the possibility that highly anaplastic carcinoma could simulate sarcoma in some areas.

In their report of a case of carcinosarcoma of the breast, Harrington and Miller mentioned the confusion caused by such names as carcinosarcoma, sarcocarcinoma, adenosarcoma, carcinoma sarcomatodes, sarcoma carcinomatodes and others. This confusion can best be avoided by the use of clearly descriptive names such as "mixed sarcoma and carcinoma" rather than one of the more striking terms.

Harrington and Miller also presented several theories of origin of such mixed malignant tumors. According to one theory both elements orig-

inate from a single parent cell, as may a teratoma. Another theory proposes that the two types of malignancy may arise independently as discrete tumors which may or may not become intermingled. A third suggests that either the carcinoma or sarcoma appears initially and then exerts some influence on the adjacent tissue causing it also to undergo malignant change.

The files of the Clinic include the records of 5 cases in which a diagnosis of carcinoma and sarcoma arising in a fibro-adenoma was made. Needless to say, this figure does not include those breasts which contained fibro-adenomas as a finding incidental to carcinoma elsewhere in the breast.

REPORT OF CASE

A nullipara aged 41 years was first seen at the Clinic in January, 1947. She complained of a mass and soreness in the left breast which she had first noticed five weeks earlier. Her mother had died of carcinoma of the breast at the age of 39 years. The patient's past history was noncontributory. She had had no previous complaints referable to the breasts, and no known injury. Systemic review disclosed only mild dysmenorrhea and menorrhagia.

Physical examination revealed a mass, 4 by 3 by 2 cm., in the upper lateral quadrant of the left breast. The uterus was nodular and about the size encountered at three months' pregnancy. Laboratory examination revealed no abnormality of the urine. There was a moderate hypochromic anemia, the hemoglobin measuring 10.5 gm. per 100 ml. of blood and the erythrocytes numbering 4,740,000 per cubic millimeter. There was slight leukocytosis (12,000 per cubic millimeter), the sedimentation rate was 26 mm. in one hour and the prothrombin time was 25 seconds (normal 19 seconds). Clinical diagnoses of tumor of the left breast (malignancy to be ruled out) and uterine fibroids were made.

Operation was performed January 22, 1947. The mass was excised for examination and a radical mastectomy performed. The surgical pathologist reported an encapsulated malignant neoplasm which showed a mixture of grade 3 adenocarcinoma and grade 3 fibromyxosarcoma which probably arose in a pre-existing fibro-adenoma (figs 429 and 430). Thirteen axillary lymph nodes were identified and examined. None showed metastatic involvement.

The postoperative course was uneventful and on February 18, 1947, total abdominal hysterectomy, bilateral salpingo-oophorectomy and appendectomy were performed. The uterus contained multiple adenomyomas, the largest being 9 cm. in diameter. There was also endometriosis of the pelvic peritoneum and the left ovary, and both ovaries contained multiple follicular cysts. Two courses of roentgen therapy to the left side of the thorax and the left axilla were given at the Clinic and a third elsewhere.

The patient returned to the Clinic in May, 1948, because of a lump in her right breast which she had first noticed three weeks before and which was growing rapidly. There also had been some soreness in the breast for about five weeks. Systemic review disclosed that she had had hot flushes, which were relieved by



Fig. 429.—1. Fibro-adenoma and sarcoma. Mitotic figures are plentiful in each (hematoxylin and eosin $\times 185$).

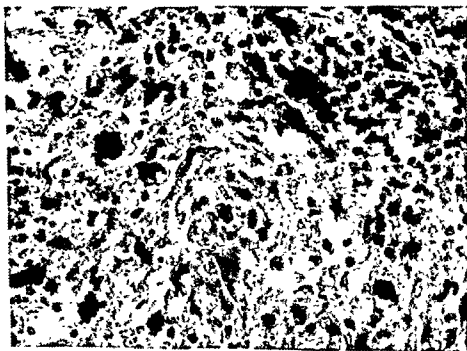


Fig. 430.—The sarcomatous portion of the tumor under higher magnification. Several atypical mitotic figures are apparent (hematoxylin and eosin $\times 390$).

INTUSSUSCEPTION IN INFANTS AND CHILDREN

ROBERT H. GIBSON, MALCOLM B. DOCKERTY, AND CLAUDE F. DIXON

Intussusception is one of the important diseases which necessitates emergency surgical treatment in the early years of life. During this period it is perhaps the commonest cause of intestinal obstruction. Intussusception may be completely and usually permanently cured by prompt treatment, usually of a surgical nature, yet tragedy often results if indecision and procrastination have occurred before the institution of surgical treatment. In spite of the accumulation of literature on this subject, throughout the years, the mortality rate in cases of this disease has been extremely high. This indicates a need for a more widespread knowledge of the characteristics of this condition in order that one may more often think of it as a diagnostic possibility and thus insure prompt application of therapy.

Leichtenstern said that intestinal obstruction has been recognized since the times of Hippocrates and Galen, but that particularly during the sixteenth century, under the influence of the beginning science of human anatomy, knowledge of the anatomic lesion underlying intestinal obstruction gradually increased. Readlus Columbus, Fabricius Hildanus and Riolan, all anatomists, are credited with having ably described intussusception separately in the sixteenth century. Nyborg said that in 1627 a French surgeon, François Rauchin, first suggested that intussusception be excluded from the collective term "ileus." He (Nyborg) said that the first specific clinical observations on this disease were made by Kuhn in 1702, Velse in 1742, and by Hevin in 1728. According to Clubbe, John Hunter gave one of the clearest early descriptions of this disease in the eighteenth century.

For many years there was apparently no rational form of treatment, for, as Clubbe said, "Old superstitions and old methods of treatment die hard." Jonathan Hutchinson in 1874 reported the first case in which abdominal section was performed on a child for intussusception. The result was excellent. Hutchinson was able to find reports of only 3 previous cases in which this operation has been performed for intussusception. In these cases, however, the patients were adults. Since the publication of the paper of Hutchinson, the treatment of this disease has definitely inclined toward surgical intervention, particularly in Great Britain and the United States. In part, this trend was aided by the introduction of aseptic surgery in the latter part of the nineteenth century. Nevertheless, largely through the efforts of Hirschsprung, a conservative method

of treatment was evolved and systematized. Such a method involved extra-abdominal taxis and injection of fluids into the intestine while the patient was under the influence of a general anesthetic. This method or a modification of it is looked upon with favor in not a few institutions, particularly those in the Scandinavian countries and in Australia.

In the years intervening, the literature concerning this disease has grown tremendously. Many excellent contributions and reviews concerning all phases of this condition have been presented, by Fitzwilliams, Romanis, Clubbe, Perrin and Lindsay, Hipsley, Monrad, Ladd and Gross,^{11 12} and more recently by Nyborg, Gibbs and Sutton, as well as by Oberhelman and Condon. An exhaustive review of the literature is not within the scope of this paper as the subject has been amply covered by other writers.

As previously mentioned, the mortality from fully developed intussusception among infants and children has been inordinately high. The purpose of this paper is to review a number of cases of intussusception in which the patients have been treated surgically and to present pertinent data relative to the disease. Various signs and symptoms will be emphasized to aid in its diagnosis, the various methods of treatment will be evaluated and the factors influencing the prognosis will be considered.

MATERIAL AND METHOD OF STUDY

This report is based on a study of 62 consecutive cases in which infants and children who were less than 15 years of age underwent an operation for intussusception at the Mayo Clinic in a period of twenty-seven years, namely, from 1920 to 1946, inclusive.

In each case, the clinical history and the surgical record were studied. Tissues that had been removed at operation were studied with reference to their gross and microscopic characteristics. Specimens that contained a demonstrable organic lesion such as a tumor or Meckel's diverticulum were studied in more detail with reference to the pathogenesis of the intussuscepting lesion.

In the literature, intussusception commonly is classified as acute, subacute and chronic, depending chiefly on the duration of the symptoms. We have followed this classification in our study. According to Bergstrom, intussusception should be classified as subacute if the resulting symptoms have been present for at least a week. In cases in which the symptoms had been present for more than two weeks, Ladd and Gross¹¹ classified the intussusception as chronic. In the 62 cases which form the basis of our study, the intussusception was classified as follows: acute in 56 cases, subacute in 4 cases, and chronic in 2 cases. The 56 cases of acute intussusception will be considered separately while the 4 cases of subacute

intussusception and the 2 cases of chronic intussusception will be considered together.

ACUTE INTUSSUSCEPTION

In our series of 56 cases of acute intussusception, the disease seemed to occur more frequently in the spring and summer than it did in the fall and winter. We realize, however, that our series of cases is too small to warrant any definite conclusions regarding the seasonal incidence of the disease. The ages of the patients ranged from 2 months to 13 years. In 38 (67.8 per cent) of the cases, the patients were less than 1 year of age; in 44 (78.5 per cent) of the cases, the patients were less than 2 years of age. In 36 (64.2 per cent) of the 56 cases, the patients were boys; in the remaining 19 cases (33.9 per cent), the patients were girls. Actually, there were only 55 patients in this series of 56 cases. One of the boys underwent an operation for acute intussusception on 2 different occasions. Each instance of the disease has been classified as a separate case for statistical purposes. All of the patients belonged to the white race.

In 40 of the 56 cases, the nutritional status of the patients was noted at the time of their admission to the hospital. Thirty-six (90 per cent) of these 40 patients were well nourished, 2 (20 per cent) were fairly well nourished, and 2 were poorly nourished. Both of the patients who were poorly nourished survived the operation.

Signs and Symptoms.—Pain or its manifestations had been noted in 53 (94.6 per cent) of the cases. In 39 (69.6 per cent) of the cases there was a history of the passage of blood in the stools or of the presence of blood on the physician's finger after he had completed a rectal examination. In 9 additional cases, blood was passed in the stools after the administration of an enema. The history or the clinical findings, therefore, revealed evidence of hematochezia in 48 (85.7 per cent) of the cases. A history of vomiting was recorded in 45 (80.3 per cent) of the cases. In 4 of these 45 cases, pain either had not been present or its presence had not been recorded in the history.

A mass could be palpated in 44 (78.5 per cent) of the cases. The mass could be palpated through the abdominal wall in 41 (73.2 per cent) of the cases and rectally in 15 (26.7 per cent) of the cases. In 3 of the 15 cases in which a mass could be palpated rectally, examination of the abdomen did not disclose any abnormality. Dance's sign, that is, a depression in the right iliac region, was not observed in any of the 56 cases. These physical findings were elicited before the patients were anesthetized.

In 51 (91.0 per cent) of the cases, 3 or more of the cardinal signs and symptoms of intussusception, namely, pain, vomiting, a palpable ab-

dominal mass and the passage of blood in the stools, were present. In 27 (48.2 per cent) of the cases, all of these cardinal signs and symptoms were present. Roentgenologic examination of the intestine with a barium enema was not performed in any of the 56 cases of acute intussusception.

Pathology.—*Type of Intussusception*—The intussusception was of the ileocecal type in 41 (73.2 per cent) of the cases (Table 1). In this type, the ileocecal valve leads the intussusceptum. In 8 (14.2 per cent) of the cases, the intussusception involved only the small intestine. In 7 of these 8 cases, it was classified as ileo-ileac, in the remaining case, it was classified as jejuno-ileac. The intussusception was of the ileocolic type in 4 (7.1 per cent) of the 56 cases. In this type, the ileum first becomes invaginated into itself, after which the terminal portion of the ileum passes into the colon from a second leading point. In 2 cases (3.5 per cent) the

TABLE 1
ANATOMIC TYPE OF ACUTE INTUSSUSCEPTION AND CORRESPONDING MORTALITY
IN 56 CASES

Anatomic type of intussusception*	Cases	Deaths	
		Number	Per cent
Ileocecal	41	7	17.1
Ileo-ileac or jejuno-ileac	8	1	12.5
Ileocolic	4	3	75.0
Colic	2	0	
Double	1	1	100.0
Total	56	12	21.4

* As determined at operation

intussusception was colic. A double intussusception was encountered in 1 case. Table 2 shows the mortality according to the type of intussusception.

Demonstrable Etiologic Agents.—An etiologic agent was noted in only 5 (8.9 per cent) of the cases. The etiologic agents were as follows: Meckel's diverticulum in 2 cases, an enterogenous cyst in 1 case, a polypoid lymphosarcoma of the ileum in 1 case, and a congenital band across the ileocecal juncture in 1 case. Both of the diverticula had become inverted to form the head of the intussusceptum.

Enlargement of the mesenteric lymph nodes was noted in 8 (14.2 per cent) of the cases. The enlargement of the lymph nodes was not referred to as the cause of the intussusception in any of these cases. None of the enlarged lymph nodes was removed for biopsy.

Surgical specimens were available in 5 of the 7 cases in which resection of the intestine was performed for irreducible or gangrenous intussuscep-

tion. A study of these specimens failed to reveal any necessary lesion which would account for the intussusception. Gross examination of the specimens revealed areas of necrosis which were clearly demarcated from the viable intestine. Microscopic examination revealed that the pathologic changes ranged from severe inflammation to extensive necrosis, disintegration and decomposition of tissues. The general pathologic picture was unequivocally that of hemorrhagic infarction.

Mortality.—Twelve (21.4 per cent) of the patients died. One patient died in the operating room. The most common causes of death were shock and general peritonitis (Table 2).

TABLE 2
CAUSES OF DEATH IN 12 CASES OF ACUTE INTUSSUSCEPTION

	Cases
Shock	4
General peritonitis	2
Pulmonary edema	1
Pneumonia	1
Gangrene of ileum (toxemia)	1
Undetermined*	3

* Necropsy not performed

TABLE 3
RELATIONSHIP OF PREOPERATIVE RECTAL TEMPERATURE TO MORTALITY IN 56 CASES OF ACUTE INTUSSUSCEPTION

Preoperative Rectal Temperature, Degrees F.	Cases	Deaths	
		Number	Per cent
Less than 100	19	2	10.5
100 to 102	31	6	19.3
Higher than 102	6	4	66.6

Convalescence.—In 41 (74.5 per cent) of the 55 cases in which the patients were alive when they left the operating room, the temperature reached 103° F. after the operation. Some type of postoperative complication occurred in 8 cases. Wound infection was the most common complication.

Recurrent Intussusception.—The intussusception recurred in 1 (1.8 per cent) of the 55 cases in which the patients were alive when they left the operating room.

Factors Which May Influence Prognosis.—Certain factors have been said to influence the prognosis in cases of acute intussusception. We have tried to evaluate the influence of these factors in this series of cases.

Preoperative Rectal Temperature.—The relationship between the preoperative rectal temperature and the mortality is shown in Table 3.

Duration of Symptoms.—Table 4 shows the relationship between the duration of symptoms and the mortality. With 1 exception, which was observed in the 10 cases in which the symptoms had been present for from twenty-four to thirty-six hours before the patients were brought to the clinic, the mortality appeared to increase with the duration of the symptoms. This apparent discrepancy possibly may be attributable to the small number of cases in our series.

Leukocyte Count.—A leukocyte count was made in 44 of the 56 cases. It did not appear to have any effect on the prognosis in these cases.

Anatomic Type of Intussusception.—Table 1 shows the relationship between the anatomic type of the intussusception and the mortality.

TABLE 4
RELATIONSHIP OF DURATION OF SYMPTOMS TO MORTALITY IN 56 CASES OF ACUTE
INTUSSUSCEPTION

Duration of Symptoms, hr	Cases	Deaths	
		Number	Per cent
0 to 12	14	0	
12 to 24	13	2	15.4
24 to 36	10	4	40.0
36 to 48	9	2	22.2
48 to 72	7	2	28.6
72 to 96	3	2	66.7
Total	56	12	21.4

Progress of the Intussusceptum.—The progress of the intussusceptum was noted in 43 cases. The relationship between the progress of the intussusceptum and the mortality was inconstant in these cases.

Reducibility of the Intussusception.—In 49 (87.5 per cent) of the 56 cases, the intussusception was found to be reducible at the time of the operation. The surgical treatment employed in these cases and the corresponding mortality are shown in Table 5. Death occurred in 9 (18.3 per cent) of the 49 cases. It will be noted that death occurred in 4 of the 26 cases in which a preventive operation was performed after reduction of the intussusception. Appendicostomy was the preventive operation that was performed in each of these 4 cases.

The intussusception was found to be irreducible in 7 (12.5 per cent) of the 56 cases. It was necessary to resect a portion of the intestine in these cases. The type of resection employed and the corresponding mortality are shown in Table 6. Death occurred in 3 (42.8 per cent) of the 7 cases. Two of the 7 patients were 4 months of age; the remaining 5 patients were 7, 8, 9, and 10 months, and 7 years of age, respectively.

Effect of Treatment.—In an attempt to evaluate the effect of the more frequent use of the parenteral administration of fluid and electrolytes, the effect of the more frequent use of blood and plasma, and the effect of the use of chemotherapeutic and antibiotic agents, the 56 cases were divided into 2 chronologic groups. The first group included 25 cases in which the

TABLE 5
OPERATIVE PROCEDURE AND CORRESPONDING MORTALITY IN 49 CASES OF
REDUCIBLE INTUSSUSCEPTION

Operative Procedure	Cases	Deaths	
		Number	Per cent
Reduction of intussusception	12	2	16.6
Reduction and appendectomy	8	1	12.5
Reduction and preventive operation*	26	4	15.3
Reduction and exteriorization of ileum	2	2	100.0
Reduction and Meckel's diverticulectomy	1	0	
Total	49	9	18.3

* The preventive operation consisted of appendicostomy in 17 cases, plication of the mesentery in 4 cases, fixation of the involved segment of the intestine to the cecum and ascending colon in 3 cases, and fixation of the involved segment to the parietal peritoneum in 2 cases.

TABLE 6
TYPE OF RESECTION AND CORRESPONDING MORTALITY IN 7 CASES OF IRREDUCIBLE
INTUSSUSCEPTION

Type of Resection	Cases	Deaths
End-to-end ileo-ileostomy	2	1
End-to-end ileo-ileostomy and proximal ileocolostomy	1	1
Side-to-side ileo-ileostomy	2	1
End-to-side ileocolostomy	1	0
Exteriorization operation (Mikulicz)	1	0
Total	7	3 (42.8 per cent)

patients were treated at the clinic in the years 1920 to 1937 inclusive; the second group included 31 cases in which the patients were treated in the years 1938 to 1946 inclusive. Death occurred in 5 (20 per cent) of the first group of cases and in 7 (22.5 per cent) of the second group. Further inquiry revealed that the average duration of symptoms before the patients were brought to the clinic was 25.5 hours in the first group and 34.8 hours in the second group.

SUBACUTE AND CHRONIC INTUSSUSCEPTION

In the 6 cases of subacute or chronic intussusception, the average age of the patients was somewhat higher than it was in the 56 cases of acute intussusception. In the 6 cases of subacute or chronic intussusception, the patients were 10 months, 3½ years, 6 years, 9 years, 10 years and 14 years of age, respectively.

Pain, vomiting, and constipation had been present in all of the cases but hematochezia had occurred in only 2 cases. An abdominal mass could be palpated in only 1 case. Roentgenologic examination with a barium enema was performed in 1 case. This diagnostic procedure disclosed the intussusception in this case. It is interesting to note that subsequent laparotomy disclosed that the barium enema had reduced the intussusception completely.

In another case, the surgeon was able to reduce the intussusception. In the 4 remaining cases, the intussusception was found to be irreducible or gangrenous. In 2 of these cases, the involved segment of the intestine was resected and an end-to-end anastomosis was performed. An ileocolostomy was performed in 1 case. In the remaining case, the surgical treatment included an enterostomy and a subsequent ileocolostomy.

Pathology.—The intussusception was of the ileocecal type in 4 (66.6 per cent) of the cases. In 1 case, it was of the ileocolic type. In the remaining case, it involved the small intestine. Examination of the surgical specimens revealed that the changes in the wall of the involved segment were similar to those observed in the acute form of the disease.

Demonstrable Etiologic Agents.—In 2 (33.3 per cent) of the cases, examination disclosed a lesion which had caused the intussusception. The causal lesion was an adenomatous polyp of the ileum in 1 case and a stenosing lymphosarcoma of the ileum in the other case.

COMMENT

When acute intussusception occurs in children, it most frequently affects those who are less than 2 years of age. It affects boys more frequently than girls. In most of the cases, the children are well nourished.

If the physician is alert to the possibility that this disease may be present, its diagnosis is not difficult. This is illustrated by the fact that 3 or more of the cardinal signs and symptoms, namely, pain, vomiting, a palpable mass in the abdomen and the passage of blood in the stools, were present in more than 90 per cent of the 56 cases of acute intussusception.

An abdominal mass could be palpated through the rectum in 15 (26.7 per cent) of the 56 cases of acute intussusception. In 3 of the 15 cases in which an abdominal mass could be palpated rectally, palpation of the

abdomen did not reveal any evidence of the mass. This illustrates the diagnostic value of rectal examination in cases of intussusception.

In most cases, the intussusception can be reduced after the abdomen has been opened. Every effort should be made to reduce the intussusception by simple means at the time of operation. Each additional surgical procedure is reflected by an increase in the mortality. Prolonged attempts at reduction are not without danger. The resulting shock may be so severe that the child may not be able to withstand an additional surgical procedure.

Although the mortality associated with resection of the intestine is particularly high in cases in which the patients are children, it seems advisable to excise all of the intestine which is nonviable or of doubtful viability. Such operative procedures as the one described separately by Jessett and Barker, that is, removal of the intussusceptum through an incision in the intussusciptum, should not be used because of the increased danger of infection. In cases in which resection is necessary, the operative procedure of choice is excision of the involved segment with immediate anastomosis or an operation of the Mikulicz type. Since resection was performed in only 11 of the 62 cases in our series, definite statements cannot be made regarding the safest operative procedure. Resection was performed in 7 of the 56 cases of acute intussusception. Death occurred in 3 of the 6 cases in which the resection was followed by immediate anastomosis of the intestine (Table 6). An exteriorization operation (Mikulicz) was performed in the remaining case, and the patient survived.

Ladd and Gross¹² reviewed the literature on this subject and reported 30 cases in which resection was performed. They were unable to make any definite statement regarding the operative procedure of choice. More recently, Dennis and Toon said that resection followed by immediate anastomosis is the proper treatment. No death occurred in the 7 cases in which they used this type of treatment. Perhaps, as Gibbs and Sutton have said, the surgical procedure must be chosen for the individual patient.

Clubbe has asserted that the use of additional surgical procedures designed to prevent the recurrence of intussusception is an example of misdirected surgical zeal. Other authors have expressed the same opinion and have said that such procedures should not be employed unless there is urgent need for the removal of another lesion. In addition to simple reduction, procedures designed to prevent the recurrence of the intussusception were employed in 26 of the 56 cases of acute intussusception. Paradoxically, in the 12 cases in which simple reduction was the only surgical procedure employed, the mortality was slightly higher than it was in the 26 cases in which an additional procedure was employed to prevent recurrence of the intussusception (Table 5). It would seem that the

surgical risk probably was better in the cases in which an additional surgical procedure of this type was employed. Since it is questionable whether the use of an additional surgical procedure will prevent recurrence of the intussusception, and since intussusception seldom recurs, it seems reasonable to assume that the use of such procedures may affect the prognosis adversely by prolonging the operation.

While the site of the intussusception and the height of the fever before operation may have some effect on the outcome of the disease, the factor which has the greatest effect on prognosis is the duration of the symptoms before treatment is instituted. Table 4 indicates that the prognosis is excellent if treatment is instituted early. Death occurred in 12 (21.4 per cent) of the 56 cases of acute intussusception. The mortality rate can best be reduced by early diagnosis and by the institution of surgical treatment immediately after the diagnosis has been made.

The subacute and chronic types of intussusception rarely affect children. When they do, they usually occur in children who are slightly older than those who are affected by acute intussusception. The symptoms are less severe than those of acute intussusception. Blood seldom is passed in the stools and palpation usually fails to reveal any evidence of a mass in the abdomen. Although radical surgical treatment frequently is required in cases of subacute or chronic intussusception, the prognosis is good.

SUMMARY

When acute intussusception occurs in children, it usually affects those who are less than 2 years of age. It has a tendency to affect healthy boys. An etiologic agent can be found in only a small percentage of cases. It usually is Meckel's diverticulum or a neoplasm. The most frequent site of the intussusception is the ileocecal segment of the intestine. In 90 per cent of cases of acute intussusception, 3 or more of the cardinal signs and symptoms of the disease, namely, pain, vomiting, a palpable abdominal mass and hematochezia, are present.

In most of the cases, the intussusception is found to be reducible at the time of operation. Since resection of the intestine for irreducible or gangrenous intussusception is a formidable procedure, especially in cases in which the patients are infants, every effort should be made to reduce the intussusception by simple means. No particular type of resection was found to be safer than another in our series of 56 cases of acute intussusception. Since the intussusception rarely recurs, the use of additional operative procedures designed to prevent a recurrence cannot be recommended. The most important factor which affects the prognosis is the duration of the symptoms before surgical treatment is instituted.

The subacute and chronic types of intussusception are rare. They

usually occur in children who are older than those who are affected by acute intussusception. The prognosis is good in cases of subacute or chronic intussusception.

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REPAIR OF DEFECTS OF THE SHAFTS OF LONG BONES

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Defects in the shafts of the long bones have long offered a real problem in reconstructive surgery. Before the days of the massive onlay bone graft, advocated by Albee, Henderson,^{9, 10} Campbell, and others, most such defects resulted in amputation. The restoration of large defects in the continuity of the long bones is a much more difficult problem than that of the repair of the average nonunion. Nevertheless, since the advent of chemotherapy and the antibiotics, the use of two opposing massive grafts as advocated by Boyd,^{2, 3} and the revival of the popularity of apposing half-cylinder grafts, originally described by Hey Groves, many extremities heretofore sacrificed are now being made useful.

Such defects may result from gunshot wounds, congenital anomalies, osteomyelitis, or resection for such conditions as tumors. Each case presents an individual problem that must be considered on its own merits; especially is this true if the defect has occurred during the growing years of life, since associated secondary deformities are then common unless the continuity of the bone is quickly restored. Loss of the continuity of bone due to congenital absence or after resection for tumor usually offers a somewhat different type of problem and will not be considered in this paper.

Certain basic principles in the operative technic employed in these reconstructive procedures on bone have been repeatedly emphasized by such authors as Henderson,¹¹ Murray, and others. However, before actually proceeding with the reconstruction of bone itself, there are other considerations of equal importance that must also be weighed. Following is a brief recapitulation of these several factors.

PREOPERATIVE CONSIDERATIONS

1. **Freedom From Infection.**—This factor has been stressed by most writers and is, of course, of paramount importance. Whereas formerly it was felt that a minimal period of six to twelve months should elapse after the cessation of all drainage before definitive reconstruction of such magnitude should be undertaken, this period has been materially lessened by the use of chemotherapeutic agents and the antibiotics.

2. **Good Skin.**—The importance of this factor was re-emphasized during the recent war. The use of skin plastic methods employing split-thickness, full-thickness, or pedicle grafts is, in many instances, a necessary prerequisite before attention can be turned to the bone defect itself.

3. **Adequate Blood Supply.**—Not only should the general vascular

status be good but careful attention must be paid to the local circulatory status at the operative site. If this has been impaired it can often be improved by supplying good skin, together with the excision of dense adherent scar and sclerotic bone. It is our opinion that insufficient attention has been paid to this latter detail in the past. Although the fibrous tissue in the region of the bone defect is usually excised in an attempt to improve the blood supply, bone grafts have often been applied to very dense and sclerotic bone which is incapable of being invaded by capillaries from the surrounding healthy tissue. In the usual case of nonunion it may not be necessary to excise the fibrous tissue between the ends of the bone as has been demonstrated by Phemister. However, since the problem in the repair of defects of bone is much more extensive we believe the chances of successful repair are enhanced by attention to this detail.

4 The Neurologic Status.—This must be considered in detail. Obviously, one is not justified in performing some extensive reconstructive procedure when the extremity might be of very limited value because of partial or complete interruption of the nerve supply.

5. Muscles and Tendons.—Muscles and tendons, available for the mobilization of the part, must be present or restoration of motor power possible before reconstructive procedures on the bone are justified.

6. The Mental Outlook.—Determination of the patient's mental status is of much importance. Unless he has the will and the mental stamina to go through one, and sometimes several, major operative procedures, prolonged immobilization in plaster, and a long rehabilitation program it may well be that amputation is the surgical choice.

7 The Age, Sex, Social and Economic Status.—These factors also should be given careful consideration before deciding what, if any, reconstructive operation is justified.

OPERATIVE PROCEDURES

Key and Ghormley, among others, have reviewed the operative procedures, together with the types of bone grafts, which are at the disposal of the surgeon. Of the various procedures which have been used for the repair of massive defects in the shafts of long bones, the following are prominent among the standard methods from which one has to choose in selecting the proper procedure:

1. Direct Apposition of Existing Fragments.—In certain of the long bones, notably the humerus, one is justified in accepting a considerable amount of shortening by directly apposing the proximal and distal fragments. The fragments may be aligned in a "step-cut" fashion to obtain more contact of raw bone surfaces, or they may be placed end to end and bridged with a massive graft fixed to each fragment with two screws. It is

our opinion that if either the step-cut or the end-to-end procedure is utilized, one is wise to reinforce the part with at least one onlay graft, preferably a dual onlay graft where this is possible. Shortening of 1 inch (2.5 cm.), and sometimes more, may be acceptable in defects of the femur, although every attempt should be made to preserve full length if possible. The ends of the bone in a small defect of the tibia or radius can



Fig. 431.—*a*, Old (one year) fracture of the left radius with shortening and deformity at the wrist. *b*, One month after step-cut shortening of the ulna. The fracture of the radius shows increased consolidation.

be approximated by osteotomy or resection of a segment of the fibula or ulna, respectively, and such a procedure is justifiable in many instances (fig. 431).

2. Massive Onlay Grafts.—This type of graft is to be preferred, in most instances, in the repair of long defects to any method wherein intramedullary, osteoperiosteal or cancellous grafts, or multiple chips and shavings are used alone. Not only does the massive onlay graft, when adequately fixed to each fragment with vitallium or stainless steel screws, furnish rigid fixation but also a readily available supply of osteogenetic

elements is at hand. If space permits, and cancellous bone is readily available, we feel that osteogenesis is hastened by packing this about the operative site (fig. 432).

3. **Dual Onlay Grafts.**—This type of transplant advocated by Boyd², has all of the advantages of the massive onlay graft, and in addition, furnishes better fixation. The small atrophic ends of the proximal and distal fragments are clamped between the two apposing grafts which are



Fig. 432 —a, Defect in the shaft of the right ulna nine months after a shotgun injury. b, Appearance one year after repair with a single massive onlay tibial graft.

transfixed at each end by two metal screws. Furthermore, this type of transplant re-establishes, to a certain extent, the normal contour of the medullary cavity when the trough between the two grafts has been packed with cancellous bone, and a large source of highly osteogenetic material is again provided. In a short time the grafted region may actually be stronger than the bone at either end (fig. 433).

4. **Fibular Transplants.**—Fibular transplants have been used in the past with a fair degree of success in the repair of defects in the shafts of

long bones; especially has this been the case in the repair of defects of the tibia by the use of the so-called Huntington-Stone operation, or one of its modifications. The experience with this type of procedure at the Mayo Clinic was summarized by Meyerding and Cherry in 1941. There are several objections to the use of fibula as a transplant. This bone is



Fig. 433.—*a*, Defect in the shaft of the right ulna six months after a shotgun injury. There is minimal deformity of the wrist. *b* and *c*, Appearance nine and one half months after repair with dual tibial grafts. The wrist articulation is normal.

composed of such firm cortical bone that it is usually slowly incorporated into the host bone and often prolongs the necessary immobilization time. For the same reason hypertrophy of this bone is slow, and protection by some form of support may be necessary for years following a successful "take" because of weakness at the grafted level. Nevertheless, there still may be an occasional patient for whom this type of transplant is preferable since it does "short-circuit" a region in which there may be poor local tissues and poor blood supply together with dormant infection which it has been impossible to eradicate (fig. 434).

5. **Apposing Massive Half-Cylinder Grafts.**—This type of graft, ad-

elements is at hand. If space permits, and cancellous bone is readily available, we feel that osteogenesis is hastened by packing this about the operative site (fig. 432).

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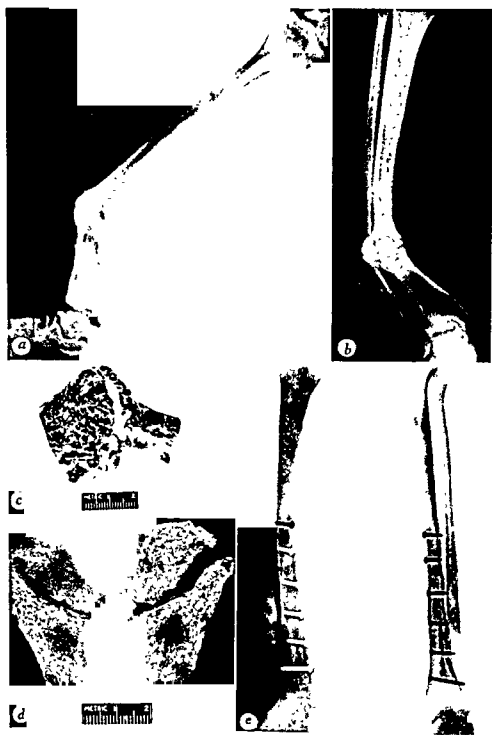


Fig. 435.—*a* and *b*, Congenital pseudarthrosis of the right tibia. The bone on either side of the pseudarthrosis is very dense and sclerotic and represents a theoretical defect.

... when to empty tibia defect with massive half-cylinder grafts and reinforcement of upper tibial donor site with iliac chips.

SPECIAL CONSIDERATIONS IN CHILDREN

In children the problem is complicated by the presence of active, growing epiphyses, and deserves special consideration. These defects should be repaired at the earliest possible time compatible with safety. Especially in the case of both bones of the forearm, and in the lower leg, when there is a massive defect in one of the bones, deformity at the joints quickly ensues unless the continuity of the affected bone is restored with-



Fig 437 —a, Defect of the distal part of the tibia in an 18-year-old girl following excision of the tibial diaphysis seven years previously for osteomyelitis. Note deformity at the knee and at the ankylosed ankle b and c, Appearance fifteen months after osteotomy of the fibula, dual bone graft for tibial defect, supracondylar osteotomy of the femur, resection of the fibular head and osteotomy of the upper part of the tibia performed in three stages.

out delay. This is well illustrated by comparison of case 7, in which several osteotomies were required to restore alignment, case 8, in which progression of the deformity was arrested but some residual deformity remained, and case 3, in which early repair made the problem relatively simple and there was no resultant deformity (figs. 437, 438 and 433).

If one bone is short at its end because of epiphyseal arrest, we feel that it is important to lengthen this bone surgically during the growth period, once or several times if necessary. This is done in an attempt to prevent secondary deformity in the remaining growth centers. Case 9 is an example (fig. 439).

REPORT OF CASES

CASE 1.—A 35-year-old man was first seen in the Clinic in June, 1928. One year previously a large rock had fallen on the left forearm and a compound fracture of both bones had resulted. After twelve weeks an open reduction had been done because of malalignment, and the record stated that "the radial fragments were wired." Examination revealed that the left ulna was abnormally prominent at its distal end, with weakness and laxity at the wrist. Roentgenologic examination showed no evidence of fracture of the ulna but there was an old fracture of the junction of the upper and middle thirds of the radius with considerable short-



Fig. 433.—*a*, Defect of the radius in an 8-year-old boy, three years after osteomyelitis and extensive sequestrectomy. Note late deformity at the wrist. *b* and *c*, Appearance three and one half months after dual tibial bone graft reinforced with iliac chips.

ening. A few days later the ulna was shortened 1.5 cm. by a step-cut, fixation being with two beef-bone screws. At the same time the triangular fibrocartilage was explored and was found to be torn away from the ulnar styloid. This was repaired. An excellent result was obtained, both bones going ahead to rapid, bony union (fig. 431).

CASE 2.—A 13-year-old boy was first seen in the Clinic in August, 1928, having received a shotgun wound of the right forearm nine months previously. Examination revealed a defect, about 2 inches (about 5 cm.) in length, in the middle third of the ulna and an old fracture of the radius united in good position. There was a draining sinus and an ulnar palsy. In July, 1929 after the sinus had been healed for several months, the defect in the ulna, which measured about 10 cm., was bridged with a single massive onlay tibial graft fastened to the proximal and distal fragments with double chromic catgut suture. The space between the bone

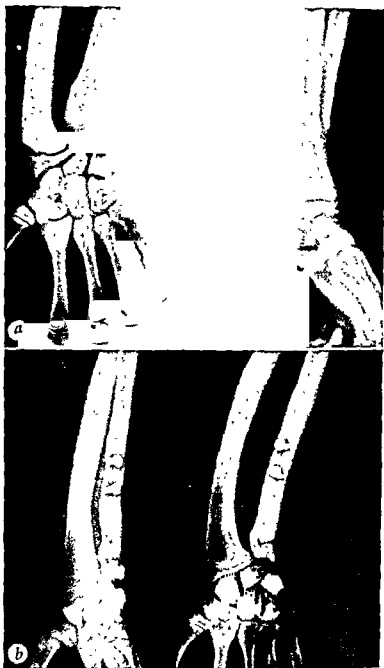


Fig. 439 —a, Defect of the left ulna of a 12-year-old girl following trauma to the epiphysis eight years previously. The radial epiphysis is very wide on the
—b, after re

ends was packed with multiple bone chips. At the same time the ends of the ulnar nerve were located. At a subsequent operation, three months later, anterior transposition and anastomosis of the nerve were done. The ulna was restored to unbroken continuity but palsy of the ulnar nerve persisted (fig. 432).

CASE 3.—A 14-year-old boy was first seen in the Clinic in February, 1947, having suffered a shotgun wound of the right forearm six months previously. The wound of entry had been repaired with a large split-thickness skin graft. Examination showed the wound to be well healed. There was partial palsy of the ulnar nerve with incomplete loss of motor function. Roentgenologic examination showed absence of the middle third of the ulna with ulnar deviation of the distal radial epiphysis. At operation the medullary canal was opened in both fragments and then the defect was bridged with dual tibial grafts, cancellous bone being packed between the grafts. Firm bony union occurred and the clinical result was excellent (fig. 433).

CASE 4.—The patient was first seen in the Clinic in 1921 at the age of 12 years, having had three operations on the left tibia for osteomyelitis of three and one half years' duration. Examination showed a large defect of the midshaft of the tibia and a draining sinus. Sequestrectomy was done. Six months later, at which time the defect measured 10 cm., a massive onlay graft was done, with two beef-bone screws used above and below for fixation; multiple bone chips were placed alongside the graft. Chronic drainage developed from the operative site and eventually the graft was lost. About five years later the patient was seen again. Her wound had been completely healed and without drainage for a year but she had been seriously considering amputation. On March 18, 1926, the first-stage of the Huntington type of procedure was done, the fibula being implanted into the proximal tibial fragment. On January 6, 1927, the second stage was done, the lower part of the fibula being transplanted into the distal tibial fragment. Post-operative convalescence was uneventful. The patient was last seen in 1944 at which time it was noted that she had not used a cane for many years, was working on her feet in a store all day long, and was very pleased with the result even though there was about 3 inches (about 7.5 cm.) of shortening (fig. 434).

CASE 5.—A 35-year-old man was first seen in the Clinic in November, 1947, having had two operations, one at the age of 4 years and one at the age of 9, for congenital pseudarthrosis of the right tibia. Examination revealed actual shortening of 4½ inches (about 12 cm.), with marked anterolateral bowing; there was quite marked secondary distortion of the talus, the talocalcaneal and talonavicular joints. Reconstruction was done on December 10, 1947. The fibula was cut at the level of the pseudarthrosis. The region of the pseudarthrosis was then excised back to healthy bone and the defect was repaired with a massive half-cylinder graft (Hey Groves) after the method described by Flanagan. Fixation was obtained with six stainless steel screws. Firm union, both clinically and roentgenologically, occurred (fig. 435).

CASE 6.—A 23 year old man sixteen months previously had suffered from a compound fracture of both bones of the forearm when the arm was caught in a revolving belt. The bones had been "wired" at once; the ulna had united but the radius had not, and a graft subsequently applied had ultimately absorbed completely. Examination showed the healed fracture of the lower third of the ulna, with absence of the lower third of the radius. The defect was surgically repaired by Dr. M. S. Henderson in July, 1918, by transplantation of a portion of the fibula including the head and about 4 inches (about 10 cm.) of the shaft; fixation was obtained by chromic catgut sutures. Firm bony union resulted and the clinical result was excellent. Further improvement, at least from a cosmetic standpoint, would probably have been obtained by resection of the end of the ulna; however, it must be remembered that this patient was operated on in 1918 (fig. 456).

CASE 7.—An 18 year-old girl about seven years previously had had excision of the tibial diaphysis for chronic osteomyelitis. After several years the wound had healed, and when first seen she was wearing a long leg brace and on several occasions had been advised to submit to amputation. Examination showed most of the tibial shaft to be present but it was very small and the distal 2 inches (about 5 cm.) was missing; the ankle joint was fused as were some of the tarsal joints. The foot was in varus and there was marked lateral and posterior displacement of the leg on the thigh. There was 2 inches of actual shortening. In the first stage of the reconstruction the fibula was osteotomized in order to correct the position of the foot on the leg; the defect was bridged with massive dual tibial grafts and packed with a large quantity of cancellous bone, fixation being obtained at the upper end with two vitallium screws. Firm union occurred rapidly, and two months after the first procedure supracondylar wedge osteotomy of the femur was done in order to correct the position of the leg on the thigh and to correct the recurvatum of the knee. Finally, two months later (four months after the first stage) transverse osteotomy of the upper end of the tibia was done in order to correctly align the tibia with the femur. The clinical result was excellent (fig. 457).

CASE 8.—An 8-year-old boy was first seen in August, 1913, with a history of having had acute osteomyelitis of the left forearm one year before. A large sequestrum had been removed from the radius. Examination showed radial deviation of the wrist and a defect of nearly 3 inches (about 7.5 cm.) in the lower third of the radius, with only about 1 inch (2.5 cm.) of the distal part of the radius remaining. It was felt that insufficient time had elapsed after the acute infection to make reconstruction safe. Accordingly, the patient went home, and he returned in June, 1915. Re-examination showed a 3-inch radial defect but an active lower

vitallium screws. One year later there was firm clinical union and the disproportion in length was less pronounced. At that time the screws were removed and the scar was excised. When growth is complete the distal end of the ulna probably need excision (fig. 438).

CASE 9—A 12-year-old girl had had two injuries to the left wrist at about the age of 4 years with subsequent growth deformity at the wrist. Examination showed the distal part of the ulna to be short, with ulnar bowing of the distal end of the radius. At operation the ulna was lengthened about $\frac{1}{2}$ inch (about 2 cm) by a step cut procedure, fixation being obtained with two vitallium screws. When the patient was last seen, two years after operation, there was practically normal function of the forearm and wrist with the exception of slight limitation of supination, there was a very slight ulnar deviation of the hand. Roentgenograms showed firm bony union of the ulna and almost complete closure of the distal radial epiphysis (fig. 439).

SUMMARY AND CONCLUSIONS

Before proceeding with reconstruction of massive defects in the shafts of the long bones the following factors must be evaluated: freedom from infection, the status of the skin, the general and local vascular supply, the status of the nerves, muscles and tendons, and the mental outlook, sex, social and economic status of the patient. When repairing a bone it is important to eradicate, as much as possible, the scar tissue and sclerotic bone in the vicinity of the defect.

The standard methods of restoring the continuity of the long bones which one has to choose are reviewed and the advantages and disadvantages of each are pointed out. This varies from bone to bone and from case to case but in general the dual tibial graft seems best suited in the majority of cases.

The problem of repair of defects of the long bones is much more urgent in children than in adults; the repair should be carried out as quickly as possible, compatible with safety. If the repair is necessarily or unnecessarily delayed, secondary deformities rather quickly develop; especially in the case when there is a defect in one of the bones of the forearm, the leg and the other continues its growth at a normal rate.

Cases illustrating the standard method of repair are reported. Also cases showing the advantages of early over late repair of defects of the long bones in children are reported.

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flap for repair of that portion of the defect involving the nose and the other end of the flap for that portion on the cheek.

Cervical and clavicular tube flaps can be considered together because they are employed for the same purpose. They supply tissue for smaller defects about the nose and cheeks. A cervical flap (fig. 413) has the advantage of reaching directly to the defect but has the disadvantage of leaving visible scarring on the side of the neck when the patient is clothed.

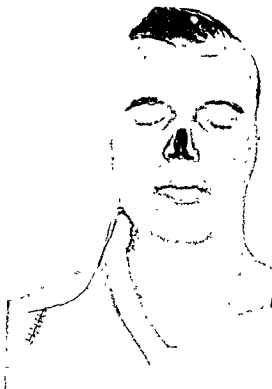


Fig. 414 —Clavicular tube flap for the repair of a nasal defect. The tube flap is elevated just below the clavicle. Four to six weeks later, the mesial end is detached and brought up to the nasal defect. This form of migration is necessary for a short tube in order that it can be elevated to the facial defect.

On the other hand, a clavicular tube flap (fig. 414) is too short to reach directly to the defect; one end must be attached to the side of the neck as an intermediary stage before the other end can be detached and transferred for the reconstructive process. In consequence, a clavicular tube flap requires an extra four weeks' time in preparation. It has the advantage, however, of not leaving visible scarring when the patient is clothed, as does the cervical tube flap.



Fig 415. — facial reconstruction because of the tube flap is lined with a full by the dotted area. *b*, Later the lower end is detached from the chest and sutured to the midcervical region. *c*, When this has healed in three or four weeks, the upper end of the tube is cut across and elevated up to the facial defect.



Fig. 416.—Reconstruction of the nose with a pedicle arm flap. My colleagues and I advocate this method of nasal reconstruction only when the forehead and trunk are scarred, prohibiting the use of forehead flaps or distant tube flaps.

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A SIMPLIFIED CLASSIFICATION OF THE GLIOMAS, BASED ON THE CONCEPT OF ANAPLASIA

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ALFRED W. ADSON

From the surgeon's standpoint, brain tumors can be conveniently classified as follows: (1) tumors of the envelopes of the brain (meningiomas, sarcomas); (2) tumors of special structures (pituitary adenomas, pinealomas); (3) tumors arising from heterotopic rests (epidermoids, dermoids, chordomas, craniopharyngiomas); (4) tumors arising from cranial nerves (neurofibromas); (5) tumors arising from vascular tissue (angiomas, hemangiomas, hemangio-endotheliomas and others); (6) metastatic malignant lesions and (7) tumors arising from neural elements (gliomas).

The surgical pathology and the degree of malignancy of the first six of these subdivisions are fairly well understood and uniformly determined. Thus, it is known that approximately 10 per cent of meningiomas are malignant meningiomas, and that certain adenomas of the pituitary show evidence of malignant change. However, with the present histogenetic concept of the gliomas and the classification based on this concept, the neurosurgeon is confronted with sixteen or seventeen subdivisions and obtains only a relative index of degree of malignancy of each.

The authors believed that a simplification of the present classification of gliomas together with the grading of the degree of malignancy within each group would be highly advantageous to the neurosurgeon. We applied the concept which is rather universally held by general pathologists in dealing with carcinoma elsewhere in the body, namely, that malignant change represents anaplastic transformation of adult cells. The neural tissue of the brain is made up of four different types of cells, and consequently when the concept of anaplastic change is applied to the study of gliomas, four types of gliomas may arise from the neural elements of the central nervous system; namely, (1) astrocytoma, (2) ependymoma, (3) oligodendroglioma and (4) neurocytoma (neuro-astrocytoma). Medulloblastoma also must be included as an entity because of its relatively constant histologic structure and its frequency of occurrence. A discussion of each of these subdivisions follows.

ASTROCYTOMA

In our group of astrocytomas, graded 1 to 4 on the degree of malignancy, we have included the following glioma subdivisions of B

Cushing: astrocytoma, polar spongioblastoma, astroblastoma and glioblastoma multiforme. The inclusion of these various subdivisions is justified on the basis of certain histologic, clinical and laboratory observations.

Russell and Bland have shown that polar spongioblastomas when grown in tissue culture, have the growth and histologic characteristics of astrocytes. The life history of polar spongioblastomas is similar to that of the astrocytomas. We also agree with Russell and Bland that the environment of the usual site of predilection of so-called polar spongioblastomas (optic nerve and pons) is responsible for the elongated appearance of these cells. We, therefore, have dropped the "polar spongioblastoma" subgroup and in our classification of the gliomas have included this tumor with the astrocytomas.

The grouping of tumors called "astroblastoma" has been severely criticized on the grounds that the limits are ill-defined and artificial. In defining this tumor subgroup, Bailey and Cushing did not adhere strictly to histogenetic dicta. Rather, they stressed a histologic architectural arrangement, a perivascular actiniform pattern of astroblasts around blood vessels. They also brought in life history of the tumor as a criterion for this group. By making this architectural pattern a prerequisite for classification as astroblastoma, they necessarily excluded many tumors in which the astroblast was the predominant cell type. On the other hand, if histogenetic dicta are adhered to strictly as was done by Ortega, and if all tumors in which the predominant cell type is the astroblast are included in the astroblastoma group, many tumors will be included which Bailey¹ would call "protoplasmic astrocytomas with anaplastic tendencies," or "low-grade glioblastomas." Roussy and Oberling, and Bergstrand did not recognize the astroblastoma subgroup, but considered these tumors with the astrocytomas. This brief summary tends to support the criticism that the boundary lines of this glioma subgroup are ill-defined.

The glioblastoma multiforme subgroup has never been satisfactorily fitted into histogenetic schemes of classification. The variegated cells of this tumor, some of which are markedly pleomorphic and others of which are multinucleated giant cells, were at first thought to be spongioblasts, and accordingly this tumor when first described by Globus and Strauss was called "spongioblastoma multiforme." However, most students in the field are agreed that none of the variegated cells found in this tumor even remotely resemble spongioblasts. It is now generally agreed that they are glial cells, although abnormal in character. Hence this tumor has been arbitrarily renamed "glioblastoma multiforme," even though there is no such cell as a glioblast. Penfield has stated that it is difficult in this tumor to select a single type of cell which can be identified with

any of the cell types in the spongioblastic series; this fact makes a histogenetic classification of this tumor a problem.

Various authors have mentioned a definite interrelationship among these three tumor groups, astrocytoma, astroblastoma and glioblastoma multiforme. Bailey and Bucy stated that the astroblastoma passes over by insensible transitions to glioblastoma multiforme, ependymoblastoma or to astrocytoma. Elvidge, Penfield and Cone expressed the opinion that the astroblastoma, histologically and biologically lies between the astrocytoma and the glioblastoma multiforme. Bucy stated that some astrocytomas occasionally undergo malignant transformation and then histologically and clinically resemble glioblastoma multiforme. Scherer has pointed out the frequency with which areas of glioblastoma multiforme are found in astrocytomas. This fact appears significant inasmuch as glioblastoma multiforme rarely is admixed with any glioma, except the astrocytoma. Furthermore, the tissue culture studies of Canti, Bland and Russell emphasised this interrelationship among these tumor groups. They have shown that the cells of the cultured glioblastoma multiforme pass over in time into astrocytes. Kernohan, in discussing brain tumors, has expressed the opinion that the astroblastoma and the glioblastoma multiforme are malignant astrocytomas.

It occurred to us in the course of our study that it might be well to lump these three tumor subdivisions together and study them as a whole. It soon became evident that within this assembled group of tumors a gradual transition occurs from least malignant to most malignant and the histologic features of the tumors of a slight degree of malignancy can be traced uninterruptedly into the most malignant ones. We, of course, saw the same cells which Bailey and Cushing considered to be astroblasts, and the variegated polymorphic cells and the mitotic figures which are said to characterize the glioblastoma multiforme. However, rather than attempt to relate these various cells to certain stages of the development of the central nervous system of the embryo, we interpreted them as anaplastic transformations of normal astrocytes. Therefore, on the basis of dedifferentiation or anaplasia, for example, pleomorphism, hyperchromatism and mitotic figures, we believe that these three tumor groups, the astrocytoma, astroblastoma and glioblastoma multiforme represent varying degrees of malignancy within a single tumor group. We have graded the tumors of this group as astrocytomas, grade 1 to 4.

In addition to the more frequently encountered fibrillary astrocytomas, we have included in this analysis the tumors in which most of the cells are protoplasmic, or gemistocytic types of astrocytes. Criteria for the various grades have been established, solely from the

histologic picture, without reference to the life history of the tumor; as follows:

Grade 1.—Astrocytomas of grade 1 are composed entirely of astrocytes which have normal nuclei with varying numbers of fairly well formed processes (fig. 440, *a*) as seen in the routine hematoxylin and eosin, Mallory-Hendemann, Mallory phosphotungstic acid stains, and in the special stains, particularly the Cajal gold chloride and sublimate stain. Although the tumor is composed of fairly normal astrocytes, the normal composition and architecture of the brain is absent. Thus, if the tumor is situated in the cortex, the normal architectonic layer pattern of ganglion cells and their processes is replaced in the central portion of the tumor by a collection of normal-appearing astrocytes. Similarly, if the tumor is situated in the white matter, a collection of normal-appearing astrocytes has partially replaced the fiber tracts. From the center of the tumor to the periphery, there is a gradual transition between tumor and normal brain, and in this transitional zone distorted, angulated, and fragmented ganglionic processes and ganglionic cells in various stages of degeneration are present. This transitional zone in grade 1 tumors is broad and ill defined. The number of astrocytes in the core of the tumor per unit area is not always materially increased over the number of astrocytes per unit area in normal brain. In those tumors in which the majority of cells are fibrillary astrocytes, the degree of fibrillary development is high (fig. 440, *b*).

The degree of vascularity of these tumors is the same as that of normal brain tissue. Adventitial proliferation is minimal and infrequent, it is found in only a very small per cent of tumors of grade 1. Intimal proliferation is minimal and very rare. These changes produce a slight thickening of the walls of vessels. In a few tumors of this grade the astrocytes have a perivascular actiniform arrangement.

Manifestations of anaplasia, such as pleomorphism of either cytoplasm or nucleus, hyperchromatism, and mitotic figures, are not present. The lesions, although composed of normal-appearing astrocytes, are none the less malignant, because they are tumefactions composed of an abnormal arrangement of astrocytes. This concept which considers a tumefaction composed of normal-appearing cells as malignant is particularly apropos of the central nervous system, in which the tissue is particularly vulnerable to the effects of a space occupying lesion.

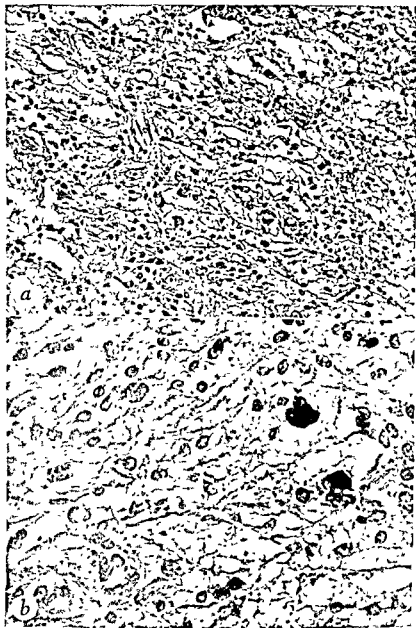
Grade 2.—The majority of the astrocytes are normal in appearance in tumors of grade 2. The general features characteristic of grade 2 tumors, for example, cellularity, transitional zone, degree of fibrillary development, vascularity, perivascular actiniform arrangement, are essentially the same as those found in tumors of grade 1. Minimal ad-



Fig. 440.—Astrocytoma, grade 1 (hematoxylin and eosin). *a*, Uniformity of structural elements is evident ($\times 150$). *b*, All the cells appear to be normal astrocytes. Note the high degree of fibrillary development ($\times 400$).

ventitial and intimal changes are encountered more frequently than in tumors of grade 1.

The remaining cells show evidence of early anaplastic change (fig.



chromatic. No mitotic figures are present ($\times 400$).

441, a). These changes consist of slight to moderate pleomorphism of cytoplasm and nucleus, together with a parallel degree of hyperchromatism. No mitotic figures are found (fig. 441, b).



Fig 442.—Astrocytoma, grade 3 (hematoxylin and eosin). *a*, Moderate evidence of anaplasia is present ($\times 150$). *b*, About one half of the cells appear to be normal astrocytes. The remaining one half are pleomorphic and their nuclei are hyperchromatic. Mitotic figures are present, averaging 1 in every other high-power field ($\times 400$).

Grade 3.—One half to three quarters of the astrocytes are normal in appearance in tumors of grade 3. The transitional zone between tumor and normal brain tissue is narrower than in tumors of grade 2. The

number of cells is increased by roughly 50 per cent over the number per unit area in normal brain tissue. The degree of fibrillary development parallels the number of normal-appearing fibrillary astrocytes which are present. Perivascular actiniform arrangement of cells is infrequently seen in this grade.

Tumors of this grade are more vascular than those of the lower grades. Adventitial and intimal thickening is more frequently encountered than in grades 1 and 2. The endothelial proliferation is pronounced; in many instances layers of four or five cells occur. Areas of necrosis are frequent throughout the tumor.

The remaining astrocytes show anaplastic transformation of moderate degree (fig. 442, *a*). These changes consist of pleomorphism of cytoplasm and nuclei, and hyperchromatism of nuclei. Occasionally polymorphonucleated and multinucleated giant cells are seen. Mitotic figures are present averaging one in every other high-power field (fig. 442, *b*).

Grade 4.—A few normal-appearing astrocytes are seen in tumors of grade 4 (fig. 443, *a* and *b*). The transitional zone is often sharply demarcated and often grossly recognizable. The number of cells is markedly increased to about three times the number of cells per unit area that are present in normal brain tissue. The degree of fibrillary development parallels the number of normal-appearing fibrillary astrocytes present. Perivascular actiniform arrangement is extremely rare. Vascularity is marked. Adventitial and endothelial thickening of the walls of the blood vessels is present in almost every instance. Endothelial proliferation is marked and may have progressed to complete occlusion of the lumen. Mitotic figures are frequently seen in the proliferating endothelium. Regions of necrosis are frequent and extensive. In the remaining astrocytes anaplastic transformation is marked. Variegated and bizarre pleomorphic changes in cytoplasm and nuclei are seen. Hyperchromatism is consequently very marked. Polymorphonucleated and multinucleated cells are abundant. Mitotic figures are abundant, averaging four or five in every high-power field.

Briefly summarized, the criteria for the various grades of malignancy of astrocytomas are as follows: Grade 1 is characterized by astrocytes of relatively normal appearance without anaplasia. Grade 2 is characterized by the early anaplastic transformation of a small number of cells. No mitotic figures are present. Grade 3 is characterized by moderate anaplastic transformation of roughly one half of the cells. Mitotic figures are present in an average of one in every other high-power field. Grade 4 is characterized by marked anaplastic transformation of most of the cells. Mitotic figures are abundant, averaging four or five in every high-power field.

Material Studied.—In 161 cases of cerebral astrocytoma in which the

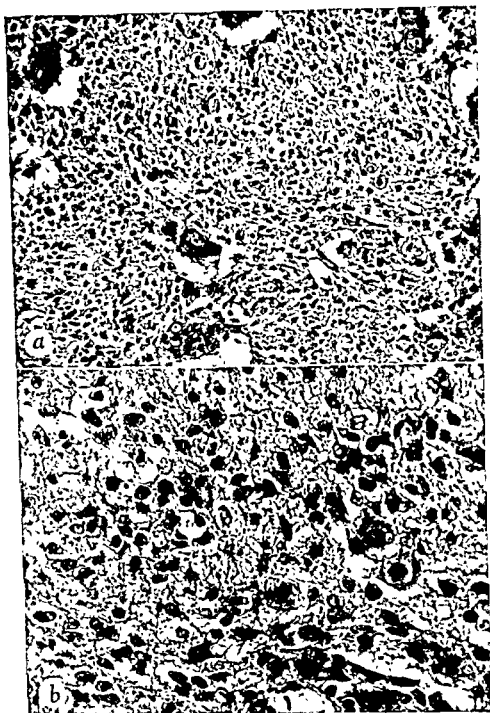


Fig 443.—Astrocytoma, grade 4 (hematoxylin and eosin). *a*, Marked evidence of anaplasia is present ($\times 150$). *b*, The majority of the cells appear to be normal astrocytes. The remaining cells are markedly anaplastic, and multinucleated giant cells are usually present. Mitotic figures are abundant, averaging 4 or 5 in every high-power field ($\times 400$).

patient survived operation by more than one month, and in which satisfactory follow-up records were available, the tumors were graded by the method outlined. Then the grade of malignancy was correlated with

preoperative duration of symptoms, postoperative survival period and age of patient. Variable factors, namely, extent of operation and postoperative irradiation therapy, were applicable to about the same degree in all four grades of malignancy. Multiple operations were done in 9 cases in this entire series, and this factor had very little effect on the average postoperative survival periods. Our results are summarized in table 1.

Thus, from this study, we have eliminated the subgroups, polar spongioblastoma, astroblastoma and glioblastoma multiforme from our classification of gliomas, and have considered these tumors, together with the astrocytomas, as astrocytomas, grade 1 to 4.

TABLE 1
ASTROCYTOMAS

Grade	Patients	Average Age, yr	Average Preoperative Duration of Symptoms, mo	Average Post-operative Survival, mo *	Three-Year Survival, per cent
1	32	33.9	20.8	73.6	62.5
2	38	38.2	11.2	23.8	15.8
3	37	40.4	11.8	11.5	14.3
4	54	42.6	7.3	6.6	3.8
Total	161				

* Since some of the patients were living at the time of this study, these figures represent minimal estimates of average periods of survival after operation.

EPENDYMOMAS

In the group of ependymomas (grade 1 to 4) we have included the ependymoma, the ependymblastoma, papilloma of the choroid plexus and the neuro-epithelioma of Bailey and Cushing's classification.

Kernohan in 1932 suggested that neuro-epitheliomas histologically and clinically were identical with ependymal-cell tumors and suggested their inclusion with this group. His suggestion has been widely accepted by neuropathologists. Therefore, we have dropped the term "neuro-epithelioma" from our classification of gliomas.

Papillomas of the choroid plexus were included as one of the ependymal-cell architectural types by Kernohan and Fletcher-Kernohan in 1937. This suggestion has met with wide approval by neuropathologists, and we have dropped the term "papillomas of the choroid plexus" as designating a glioma subtype entity.

Heretofore all the ependymal-cell gliomas in the Clinic series have been grouped, first of all, according to their architectural pattern,

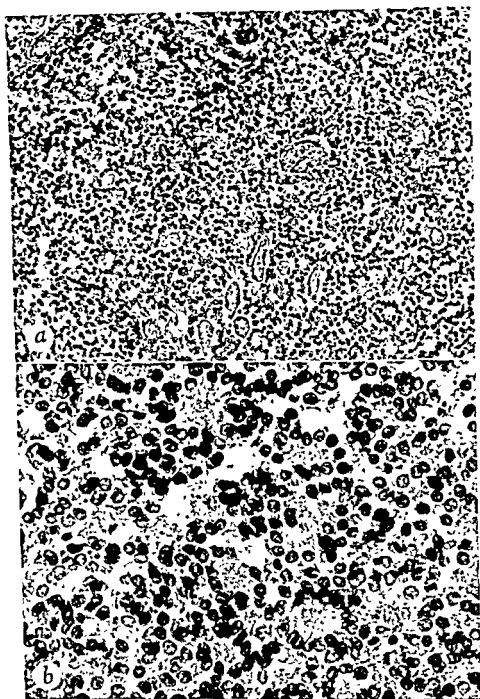


Fig. 444.—Ependymoma, grade 1.
 pattern is distinct and the structure is normal.
 b, All of the cells appear to be normal and there is no anaplasia ($\times 400$).

namely as, (1) epithelial ependymomas, (2) cellular ependymomas, (3) myxopapillary ependymomas and (4) papillomas of the choroid plexus. Then, according to the histogenetic concept of Bailey, the tumors in

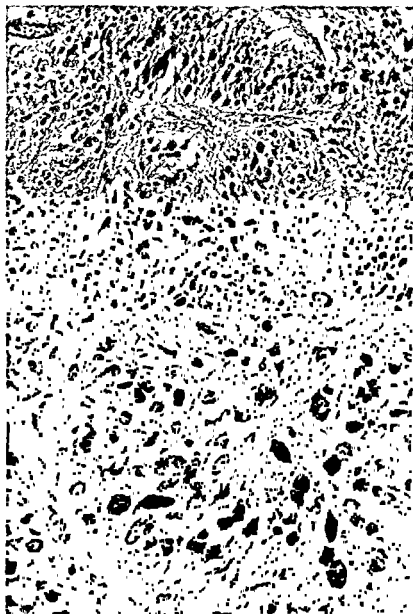


Fig. 445—Ependymoma, grade 2 (hematoxylin and eosin) a. The architectural pattern is less distinct than in ependymomas of grade 1, although it is easily

which the predominant cell type was the ependymoblast have been classified as "ependymoblastoma." This latter term is generally construed to indicate malignancy.

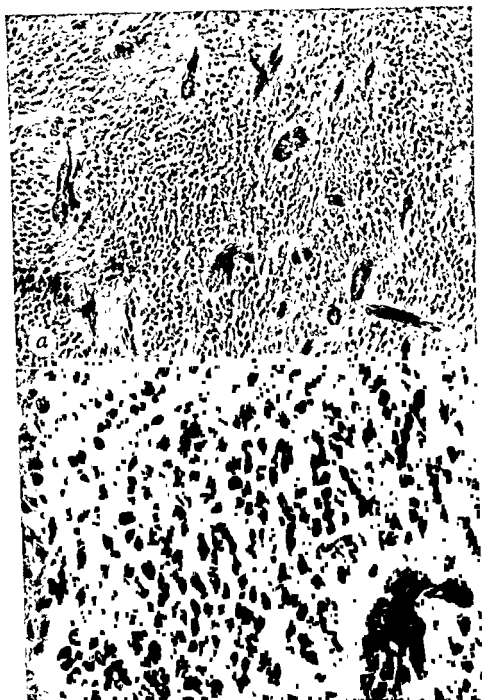


Fig. 44^e Ependymoma. The pattern, is present in the cytes, wh chromati

In a recent analysis of this group of gliomas, we failed to find any correlation between the four architectural types of ependymoma and the life history of the tumor. Moreover, the tumors which we placed in

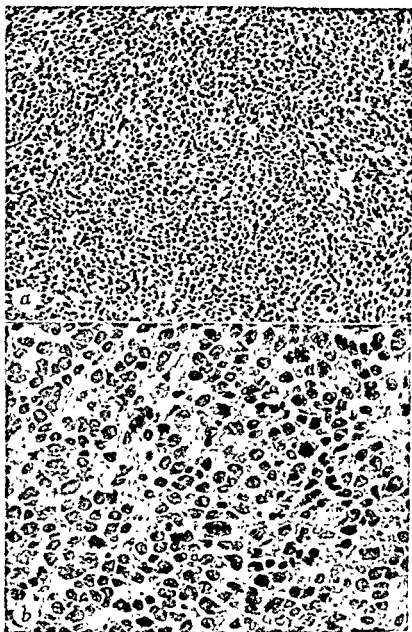


Fig. 447.—Ependymoma, grade 4 (hematoxylin and eosin) a, Although the

morphic and have hyperchromatic nuclei. Mitotic figures are abundant, about four or five per high-power field ($\times 400$)

ependymal cells of normal appearance are present with no evidence of anaplasia. In grade 2 early anaplastic transformation of a small number of cells has occurred, but no mitotic figures are present. In grade 3 roughly half of the cells have undergone moderate anaplastic transformation. About one mitotic figure is present in every other high powered field. In grade 4 the majority of cells show marked anaplastic transformation. An average of four or five mitotic figures may be seen in every high-power field.

Material Studied.—In 57 cases of intracranial ependymoma in which operation was performed, in which the postoperative period of survival was more than one month, and in which satisfactory follow-up data

TABLE 2
EPENDYMOMAS

Grade	Patients	Average Age, yr	Average Preoperative Duration of Symptoms, mo	Average Post-operative Survival, mo *	Three-Year Survival, per cent
1	30	26.1	19.8	77.0	79.3
2	8	28.5	19.6	37.7	23.6
3	9	21.0	9.0	18.2	11.1
4	10	31.3	9.1	10.1	0.1
Total	57				

* Since some of the patients were living at the time of this study, these figures represent minimal estimates of average periods of survival after operation.

were available the lesions were graded by the method outlined. Then the grade of malignancy was correlated with the preoperative duration of symptoms, the postoperative survival period, and age of the patient. Variable factors, such as extent of operation and postoperative irradiation therapy, were applicable to about the same degree in lesions of all four grades of malignancy. Multiple operations were performed in only 6 cases and therefore had little effect on the average postoperative survival figures. Results are summarized in table 2.

OLIGODENDROGLIOMAS

We have not yet studied oligodendrogliomas with the object in view of classifying them according to different grades of malignancy as we have done with astrocytomas and ependymomas. Our series of oligodendrogliomas is not now sufficiently large to be statistically significant, but we think that when an adequate number of lesions have been assembled and reviewed a system of grading their malignancy will be as

satisfactory as it has been in the types of gliomas we have reviewed. It is well known by neurosurgeons and neuropathologists that most oligodendrogliomas grow very slowly, but it is also well known that some are highly malignant and grow rapidly. These latter have been referred to as "oligodendroblastomas." We also think that there will be intermediate grades of malignancy between the two extremes. It seems to us that by designating the malignancy of these tumors as grade 1 to 4, it would eliminate the term "oligodendroblastoma" and simplify still further the nomenclature of gliomas.

NEURO-ASTROCYTOMAS

Tumors composed exclusively or even predominantly of nerve cells are found infrequently in the central nervous system. The majority of such tumors are a mixture of adult nerve cells and astrocytes or dedifferentiated cells of either of both types. These tumors could be graded 1 to 4 depending on the dominance of the anaplastic cells in the growth and the term "neuro-astrocytoma," grade 1, 2, 3, or 4 could be used. The group of tumors described by Globus as spongioneuroblastomas would thus be designated neuro-astrocytomas, grade 2 to 4, depending on the degree of anaplasia present in these tumors.

MEDULLOBLASTOMAS

Medulloblastomas are found predominantly in the midline of the cerebellum of children, although they have been found occasionally in young adults. These gliomas have a relatively constant histologic structure. The source of origin of these tumors has not yet been definitely established and we consider them tumors "sui generis." Because of their relatively constant and characteristic structure we do not think that grading the malignancy of these tumors is necessary at this time.

In all reported series of brain tumors the incidence of medullo-epitheliomas has been exceedingly low and in many series no tumor of this type has been found. In more than 4,000 tumors of the central nervous system studied at the Clinic, the diagnosis of medullo-epithelioma has been made only four times and since 1936 no examples have been encountered. In a critical restudy of these 4 tumors we found that 3 were really ependymomas, grade 4, and 1 was a medulloblastoma. Therefore, in the light of our experience, we believe that this tumor entity should be eliminated from the classification of gliomas.

MODIFIED CLASSIFICATION

The suggested modification of the classification of gliomas is presented in table 3,

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FALSE DIVERTICULA OF THE APPENDIX: A SEQUEL OF PREVIOUS INFLAMMATION AND RUPTURE OF THE APPENDIX

A Clinical and Pathologic Study

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JOHN M. WAUGH

Diverticula of the appendix have long been considered extremely rare, almost to the point of being surgical curiosities, and are still considered as such, despite the increasing frequency of reports in recent medical literature. Yet it is well established that appendixes, once ruptured, are prone to rupture again with minimal signs and symptoms and that peritonitis and a higher mortality result. This tendency to rupture easily is probably due to formation of diverticula.

Diverticula of the appendix can be classified as "true" or "congenital," which indeed are rare, and as "false" or "acquired." True diverticula are those in which all layers of the normal appendix can be identified microscopically, whereas in false diverticula the muscularis is absent, destroyed by a previous perforation at the site, or localized infection in the appendiceal wall with a resultant extrusion of the healed mucosa through the appendiceal wall. This false outpouching with absence of the muscularis must certainly be recognized as a point of weakness in the appendiceal wall, more susceptible to future infection than the remainder of the organ, and also, once infected, prone to rupture with minimal symptoms.

This study has been undertaken to determine and prove the presence of false diverticula in appendixes that have previously been the site of an inflammatory process and rupture, and since it is restricted to cases of proved inflammation, cases with previous history of appendicitis only, were ruled out in the face of possible diagnostic error, and only those in which previous rupture had been established by means of surgical exploration and drainage or by the presence of an appendiceal abscess at the time of removal were considered suitable for this study.

PARTIAL REVIEW OF LITERATURE WITH EMPHASIS ON ETIOLOGIC FEATURES

The most recent survey and study of the subject was published by Kline, Young and Straus in 1941. They discussed the literature, developmental, inflammatory and regressive changes and clinical significance of these false diverticula in addition to presenting their series of 49 cases

of false diverticula which occurred in 10,000 cases of appendicitis, an incidence of 0.49 per cent. In these 49 cases they found 85 diverticula, which were found most frequently in the distal third of the appendix. Seventy-three and nine tenths per cent of the 49 patients were females and 26 1 per cent males. The youngest patient was 13 years and the oldest 68 years of age. The majority of diverticula were found in persons in the third decade. Eighty-three and four tenths per cent were located in the meso-appendiceal side of the organ. Twenty-nine and six tenths per cent of the false diverticula were inflamed, and in this series the incidence of inflammation and perforation of the false diverticula was much greater than that of inflammation and perforation of the appendix itself. Hence the authors concluded that perforative appendicitis with false diverticula formation predisposes to perforative diverticulitis of the appendix.

Rohmer, in 1945, reported an interesting case of incarcerated inguinal hernia complicated by acute suppurative appendicitis and a diverticulum of the appendix, with nausea as the only symptom. The patient had no elevation of temperature and the leukocyte and differential counts were within normal limits. In the same year Altemeier reported a case of multiple true diverticula, two of which showed evidence of inflammation with marked lymphocytic and polymorphonuclear leukocytic infiltration present in the mucosa, submucosa and muscularis of these two diverticula.

In December, 1946, Gilmore and Mahan reported a case of diverticulosis of the appendix seen and diagnosed on roentgenologic examination. Three diverticula were visible.

Throughout the literature, the etiology of appendiceal diverticula has been the subject of rather marked dispute; yet practically all authors are of the opinion that there are both congenital and acquired types of diverticula. Undisputed cases of the relatively rare congenital diverticula, however, have been reported by Hedinger in a stillborn infant, and later by Bachlechner, Malone, von Fáykiss, Kline,²⁰ Hadley and Cogswell, Schlupfer, Rohner and Altemeier.

The etiology of the acquired or false type of diverticulum has been the subject of considerable controversy. All investigators seem to agree to the existence of some omnipresent or preformed area of weakness in the muscular wall of the appendix, yet there is a wide difference of opinion as to the origin and development.

The earliest theory as to the origin of diverticula was proposed by Weinberg in 1898. He concluded that previous inflammation and ulceration of the wall of the appendix was followed by repair and regeneration

of the mucosa, the muscularis, however, being replaced by fibrous tissue, a definite point of weakness through which the mucosa might herniate. Other later investigators,^{4, 7, 8, 10, 11, 14, 17, 19, 22, 24, 29, 31, 32, 35, 38, 43} too numerous to mention, concurred with his ideas.

Mertens proposed the theory that these diverticula occurred through gaps where the vessels penetrate the muscularis. These weak points are present normally along the mesenteric border for the most part. They also occur in the antimesenteric border but less frequently at this site. Beer, Stout, Stewart, and others concurred with this opinion.

Chase agreed with the theory that the greater number of diverticula occurred in the region of a vascular hiatus, but was of the opinion that this was due to possible rapid loss of weight by the patient, with resultant disappearance of fatty tissue about the vessel thus producing an area of weakness through which mucosa might herniate.

The traction theory was subscribed to by several authors, notably Mulsow and Wolff who described fibrous bands adhering to the appendix and the presence of diverticula at these sites.

Masson, in 1930, described hypertrophy of the musculonervous complex of the submucosa and mucosa in the presence of inflammation. This process conceivably could contribute not only to a localized weakness of the muscularis of the appendix but also to an obstruction of the lumen by further development of true neuromas. Dordick and Wolff both reported cases of diverticula in association with neuroma.

It is apparent that diverticula occur through muscular defects in the wall of the appendix, the origin of which might be due to any of the previously described causes. Several hypotheses have been advanced to explain why the mucous membrane protrudes through these defects. Practically all authors agree on the presence of increased intraluminal pressure but differ to some extent as to the origin of this increased pressure. Obstruction of the lumen proximally is present in the great majority of appendixes with diverticula. Stout, in 1923, proposed a "muscular contraction" theory, based on studies performed on dogs. He demonstrated that with operative muscular defects protrusions of the submucosa and mucosa were accompanied by active contractions of the circular and longitudinal muscles and shortening of the appendix. He assumed that the redundant mucosa herniated through the defect, seeking an outlet in the face of the muscular contraction. Edwards,¹⁰ Chase, Stewart and Galambos favored this hypothesis.

Obstruction of the lumen proximal to the muscular defect, however, seems to be the predominant factor causing increased intraluminal pressure. This obstruction may be either organic or functional. Organic

INCIDENCE, AGE AND SEX

In 35 of the 47 cases, careful study revealed false diverticula, an incidence of 74.4 per cent. It must be emphasized at this point that the 35 cases in which diverticula were found were the same 35 cases in which the major portion of the organ was available for study. The specimens from these 35 cases had previously been examined and sectioned for diagnosis at the time of operation, with removal of varying amounts of tissue, hence an accurate check as to the number of diverticula per specimen was impossible. Although there had been a total of 43 perforations in the 35 appendixes in which diverticula had been found, only one diverticulum was found in each appendix.

The average age of the 35 patients with diverticula at the time of the original drainage of the appendiceal abscess was 28.6 years, the youngest was 2.5 years and the oldest 64 years.

The number of patients who had diverticula in each decade was as follows: 0 to 9 years, 5, 10 to 19 years, 11; 20 to 29 years, 3, 30 to 39 years, 3, 40 to 49 years, 6, 50 to 59 years, 5 and 60 to 69 years, 2.

The largest number of diverticula were found in the second decade of life, which age group corresponds in ratio to the relative incidence of uncomplicated acute appendicitis.

Diverticula were found in 21 males and 14 females, a ratio of 3 males to 2 females.

SYMPTOMATOLOGY

Clinical symptoms in these 35 cases were those most often found in acute appendicitis, with those of a ruptured appendix superimposed. They were varied in degree and character to be sure, pain was the most constant finding. Generally it was intermittent and cramping in character at first, originating in the epigastrium and then localizing in the right lower quadrant, or originating primarily in the right lower quadrant. In 32 of the cases at the time of drainage of the appendiceal abscess, pain had localized in the right lower quadrant of the abdomen, and in 3 additional cases at the time of operation it was in both lower quadrants. The pain and other associated symptoms had been present from one to sixteen days prior to admission to the hospital in this series of cases.

In 32 cases nausea and anorexia were marked, and in 28 vomiting was present in varying degrees at the time of admission to the hospital.

In 8 cases there was diarrhea on admission. In these patients diarrhea was the major complaint.

Fever was noted on admission in all but 2 cases. In 4 cases the temperature was 99 to 99.9° F. on admission, in 11, 100 to 100.9°; in 8, 101 to 101.9°; in 6, 102 to 102.9° and in 4, 103 to 103.9°.

In 5 cases chills in addition to the fever were present.

PHYSICAL FINDINGS

Abdominal tenderness was most prominent in the right lower quadrant in all 35 cases. In 3 cases tenderness of lesser degree was present in the left lower quadrant and in several others there was minimal tenderness in the epigastric region. Muscle spasm and rigidity of varying degrees also were described in all cases.

On admission a palpable mass in the right lower quadrant was noted and mentioned in the records in 24 of the cases, although at operation a definite localized abscess was present and described in all 35 cases.

LABORATORY FINDINGS

Leukocyte counts varied from normal to the extreme of 28,800 per cubic millimeter of blood with an average of 15,600. In 7 cases they were from 5,000 to 10,000, in 13 from 10,001 to 15,000, in 6 from 15,001 to 20,000, in 6 from 20,001 to 25,000 and in 3 from 25,001 to 30,000.

Differential counts revealed an average of 82 per cent polymorphonuclear leukocytes with a range of from 71 to 93 per cent. Monocytes averaged 5.0 per cent with a range of from 0 to 14 per cent and lymphocytes averaged 12.9 per cent with a range of from 4 to 26 per cent.

CLINICAL DIAGNOSIS

Acute appendicitis was diagnosed in all 35 cases prior to operation and appendicitis with rupture was diagnosed in 24 of these 35 cases. At operation in the 32 cases in which drainage was employed, appendiceal abscesses were present, and in the remaining 3 cases masses which were palpable on admission had resolved somewhat prior to surgery. In the majority of cases, the main diagnostic points and criteria were typical; that is, pain localizing in the right lower quadrant, tenderness and the presence of a mass, with a history of fever, nausea, vomiting and anorexia, plus the changes in the leukocyte count.

CLINICAL COURSE

In a number of cases in which a ruptured appendix was diagnosed and in which a favorable clinical course seemed likely, the patients were treated conservatively with the hope of localization of the abscess. In these patients symptoms had been present from one to sixteen days prior to admission to the hospital with an average of 5.3 days.

Of the 32 patients on whom drainage was performed, 14 were operated on immediately on admission; in 9 other cases the abscesses were drained within seventy-two hours after admission. One patient was observed and treated conservatively for thirty-nine days prior to drainage of abscesses in both the right and left lower quadrant. The average dura-

tion of conservative treatment prior to drainage in this series of cases was 48 days.

Postoperative complications, as would be expected, were relatively high in this series. They included pneumonia in 2 cases, in 1 of which empyema subsequently developed and required drainage. In 2 cases fecal fistulas developed which drained on an average of four months; in 1 of these cases obstructive symptoms developed on two occasions but disappeared on later removal of the appendix. Another patient developed similar obstructive symptoms on three occasions but responded favorably to appendectomy. A pelvic abscess requiring posterior colpotomy in 1 case complicated the postoperative course following drainage of the abscess.

The average postoperative stay in the hospital was 20.3 days and ranged from nine to seventy-seven days, dependent of course on the complicating factors. This was a marked increase over the average postoperative stay of the patient who had ordinary appendicitis without rupture.

COURSE AFTER DRAINAGE OF ABSCESS

Of the 32 patients in whom appendiceal drainage was carried out, and who had been advised to return for interval appendectomy, 19 returned for this procedure within from one to nine months, an average of 4.6 months, without having had any symptoms. Six patients were readmitted within from two to seven months after the original surgical or spontaneous drainage because of recurrent symptoms and a second rupture of the appendix with formation of abscess. Surgical drainage was carried out a second time in these cases, an average of 4.5 months after the original drainage. The sixth patient, in whom an abscess had originally drained spontaneously through the rectum, had recurrent attacks of pain and spontaneous drainage through the rectum at intervals of approximately three months for one year, at which time it was necessary to drain a pelvic abscess from above. Thereafter there were no symptoms for a period of twenty-six months, at which time symptoms recurred. At operation a retrocecal ruptured appendix with abscess was found.

The remaining 7 patients returned with acute symptoms from two to five months after drainage, an average of 3.2 months, and appendectomy was performed at that time.

In summary, of the 32 patients who underwent surgical drainage, 13 patients returned with symptoms of acute appendicitis, either with or without another rupture of the appendix, an average of 3.9 months after the initial operation. In 6 of the 19 cases in which interval appendectomies were performed, pathologic examination revealed subacute

inflammatory changes, despite minimal or no symptoms and clinical findings. Therefore, of the total of 32 cases in which drainage was employed, 19, or approximately 60 per cent, showed either pathologic, or both clinical and pathologic evidence of recurrent inflammation within four to five months after the original drainage.

As previously mentioned, in 6 cases drainage was carried out a second time (spontaneous drainage through rectum first time in 1 case) because of another rupture with formation of abscess. At the time of the second drainage the patients were advised to return for interval appendectomy. Five of these 6 patients returned for appendectomy within three months. Two of the 5 returned with acute symptoms, one at six weeks and one at three months after the second drainage. In both cases pathologic examination of the specimen revealed subacute inflammatory changes. This sixth patient returned in twenty-six months with a third rupture and formation of a small abscess at which time the appendix was removed. Hence within an average of 6.3 months, a half, or 50 per cent, of this group of 6 patients returned with acute symptoms. One had rupture and formation of abscess.

Recurrent symptoms were essentially the same as those of the original attack, but the symptoms appeared to progress much more rapidly and were more fulminating in nature. Rupture occurred within a shorter interval following onset of symptoms than at the time of the primary rupture.

GROSS AND MICROSCOPIC FINDINGS

The diverticulum was located in the distal third of appendix in 12 cases (34.3 per cent), in the middle third in 17 (48.6 per cent), in the proximal third in 5 (14.3 per cent) and its site could not be determined in 1 case (2.8 per cent). It was located in the mesenteric border of the appendix in 14 cases (40.0 per cent), in the antimesenteric border in 8 (22.8 per cent), in the sides in 8 (22.8 per cent) and the site could not be determined in 5 (14.4 per cent).

From these figures it is evident that the mesenteric border of the appendix was the site of predilection but the antimesenteric border and sides also contained a large number.

The diverticula varied slightly in size, from 3 to 7 mm., presenting themselves as small outpouchings on the external surface of the appendix (fig. 448), with definite evidence of rupture of the diverticula in 3 cases (fig. 449), an average of approximately 8.6 per cent.

Microscopically, the diverticula consisted essentially of mucosa, fibrous tissue and serosa, and in some instances there was evidence of fatty tissue along with the fibrous tissue. The cellular components in the diverticula depended, of course, on the presence or absence of inflamma-



Fig. 448.—Diverticulum of the appendix cut through center. The break in the muscle is grossly visible, with the mucous membrane extending down through it. Tip of diverticulum covered by fatty tissue.

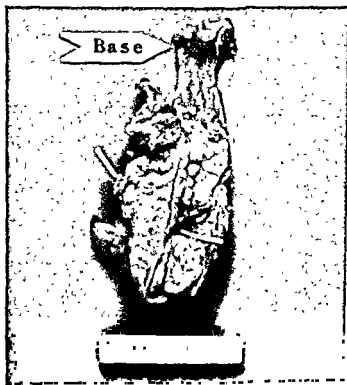


Fig. 449.—Perforated diverticulum—pointer through site of perforation.

tion (fig. 450), with eosinophils, plasma cells, lymphocytes and leukocytes identified in varying amounts. Involutional and compression changes were present in the mucosa of the diverticula in some instances. In all cases, disruption of both the inner circular and outer longitudinal layers of muscle was complete at the site of the diverticulum (figs. 451 and 452). In 4 early cases the mucosa was entirely absent, and had not been regenerated as yet, after its destruction at the time of perforation. Moderate difficulty was encountered during the search for diverticula,

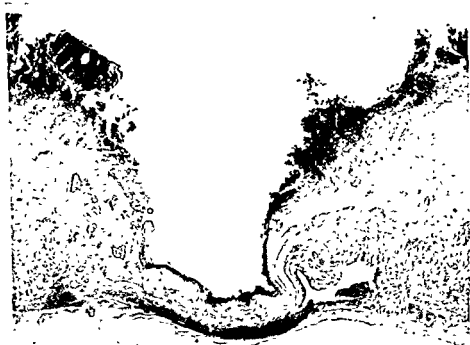


Fig. 450—Subacute inflammatory changes visible in defect. Mucosa absent ($\times 22$).

especially with those presenting along or within the leaves of the meso-appendix. Several were cut through before they were recognized because fatty tissue masked their presence.

As previously mentioned, 3 of the 35 patients were treated conservatively for periods of ten, fifteen and twenty days, after which time the appendix was removed without previous drainage of an abscess. In all 3 cases diverticula were recognized grossly, and this finding was confirmed microscopically. Both the appendix and diverticulum showed evidence of acute inflammation in each case. Hence, in these 3 cases, within an average of fifteen days after onset of symptoms, diverticula had progressed to the size of gross recognition. The mucosa had not regenerated as yet in these cases.

Of the total of 35 specimens, 16 showed microscopic evidence of active



Fig. 451.—Microscopic view of diverticulum, showing definite break in muscularis, lined by mucosa on one side. Previous rupture site visibly repaired by fibrous scar tissue ($\times 10$)



Fig. 452.—Diverticulum with mucosa dipping down and lining defect of muscularis to some extent. Scar tissue replacement of muscularis at site of previous rupture ($\times 10$)

inflammatory changes in the diverticulum proper, whereas in 10 the condition was classified as chronic.

Pathogenesis.—In this series of 35 cases the diagnosis of ruptured or perforated appendix was established clinically or at the time of operation in all cases. Formation of diverticulum followed with recognition of diverticula at the time of removal in 5 of the 35 cases in this series.

Contributing Factors.—Organic factors which may have contributed materially to increased intraluminal pressure and hence formation of diverticula included: fecaliths in 7 cases, obliteration or partial obliteration of the appendix in 2 cases, stricture proximal to diverticulum in 2 and adenocarcinoma in 1 case. A mucocele was noted in only 1 case.

It must be emphasized that various functional factors which could not be identified by pathologic examination may have been, and probably were, present to bring about increased intraluminal pressure in vivo.

TREATMENT

From the data presented it is obvious that once appendiceal rupture has occurred and the abscess drained, diverticula are likely to develop at the site of rupture. These diverticula are recognized as definite weak points, which are prone to re-infection and possibly to rupture. Interval appendectomy is the treatment of choice in cases of ruptured appendix and should be carried out as soon as the patient's general condition warrants it, preferably within two to three months after drainage of the abscess.

COMMENT

Diverticula obviously occur more commonly than noted on ordinary pathologic examination of the organ after appendectomy. Recent studies, with careful examination of the specimen, have shown a progressive increase in incidence of diverticulum.

Diverticula per se may be the end result of any one, or a combination of several pathogenetic factors as previously discussed by other authors. However, probably the most outstanding predisposing factor is that of previous inflammation and perforation of the appendix with destruction of the muscularis at the site of rupture. Repair leaves a weak fibrous scar. There is regeneration of the mucosa, submucosa and subserosa from the area adjoining the site of perforation. Stasis due to the absence of muscle in the diverticula, as mentioned by Kline and associates, may be a factor to account for the higher incidence of inflammation in the diverticulum. Perforation of the appendix itself is less common than perforation of the diverticulum. This fact must be assumed in this series from the number of perforated diverticula found (4) and the total

number of perforations (43) as compared with the number of diverticula found (35) and from comparison with the number of perforations in the appendixes in general.

Obstruction, either organic or functional, as previously reported by many authors, undoubtedly plays a large part in increased intraluminal pressure within the organ with resultant formation of diverticula, with fecaliths and fecal columns most likely heading the list of offenders, followed by obliterative reactions, strictures, and so forth.

The dangers connected with formation of diverticula should be re-emphasized. Diverticula are prone to infection, as demonstrated previously by other authors. They are weak points in the wall of the appendix and hence are prone to rupture again with possible minimal symptoms, with a resultant generalized peritonitis. The increased number of complicating factors with higher morbidity and mortality rate is a foregone conclusion with ruptured appendix.

Diverticula of the appendix are of clinical importance in the production of some cases of pseudomyxoma peritonei, as pointed out by Löhr, Masson and Hamrick, Collins,⁸ Wolff, Ries, Gardham and associates Wilson, in 1947 in his thesis, pointed out the fact that there was some relation between these false diverticula of the appendix and granulomas of the ileocecal region secondary to appendicitis.

REPORT OF CASES

CASE 1—The patient, a boy 13 years of age, was admitted to the hospital four days after the sudden onset of nausea and vomiting and generalized abdominal pain. Three days previously he began to pass eight to ten stools during the day. Pain, nausea, vomiting and diarrhea continued for two more days. The pain finally localized in the right lower quadrant twelve hours before admission.

Examination revealed marked rigidity of the entire abdomen, tenderness which was greatest in the right lower quadrant, and a mass in the right lower quadrant palpable through the abdominal wall and also by rectum.

Laboratory findings were as follows: urine normal; 12.4 gm. of hemoglobin per 100 cc. of blood and 15,200 leukocytes per cubic millimeter 76 per cent of which were neutrophils, 17 per cent lymphocytes and 7 per cent monocytes.

Emergency drainage of the abscess was performed, with a moderate amount of purulent material and gas present. Culture revealed *Escherichia coli* and gram-positive bacilli.

The patient remained in the hospital for twenty-six days after operation. Repeated probings of the site of drainage were necessary before the infection subsided. The patient and his parents were told that the boy should return for interval appendectomy.

Within the next six months the patient was admitted twice with generalized abdominal pain, distention and mild symptoms of obstruction which responded in both instances to medical management.

Approximately six months after drainage of the abscess, the patient awoke with

pain in his abdomen. This was cramping and intermittent and became progressively worse. Vomiting occurred five to six times in a period of a few hours.

On admission the temperature was 96° F., pulse rate was 70 and respirations 20 per minute. Tenderness was present over the entire abdomen, most marked about the umbilicus and right lower quadrant. No mass was present. Laboratory findings revealed 14.8 gm. of hemoglobin; 4,220,000 erythrocytes and 10,100 leukocytes of which 84 per cent were neutrophils, 14 per cent lymphocytes and 2 per cent monocytes. Symptoms subsided markedly within twelve hours and the patient was allowed to go home to finish the school year.

Appendectomy was performed approximately one month later. Several layers of ileum were adherent to the appendix and a portion of a free-lying fecalith was found when these loops were freed.

Examination of the removed appendix revealed subacute, recurring appendicitis involving principally the tip, with a diverticulum 1 cm. long covered by an inflammatory layer of peritoneum only. The diverticulum contained the other portion of the fecalith found lying free in the abdomen.

CASE 2.—The patient, a girl 10 years old, had experienced nausea and vomiting one week prior to her admission to the hospital, at which time a temperature of 101° F. was recorded. This fever lasted approximately twelve hours and then subsided. Two days later she began to have generalized abdominal pain, and because of an upper respiratory infection operation was not advised at that time. The pain localized in the right lower quadrant within the next twelve hours and increased in intensity; marked nausea and vomiting were associated.

The patient was admitted to the hospital one week after onset of symptoms at which time the temperature was 101.8° F. Marked tenderness, muscle spasm in the right lower quadrant and a palpable mass were found. Some evidence of dehydration was present. The patient was given fluids intravenously. At operation eight days after onset of symptoms an appendiceal abscess containing 30 cc. was drained. Culture showed gram-negative bacilli.

Laboratory tests showed 13.2 gm. of hemoglobin; leukocytes numbered 14,400 of which 75 per cent were neutrophils, 14 per cent lymphocytes and 11 per cent monocytes. Examination of urine gave entirely normal results.

The patient was dismissed on the tenth hospital day with instructions to return for interval appendectomy. Exactly three months after the drainage operation the patient suddenly became nauseated and complained of pain in the epigastrium and left lower quadrant of the abdomen. For four days pain became more severe and finally localized in the right lower quadrant; the pain was accompanied by moderate nausea and vomiting and mild diarrhea.

At the time of examination the patient had a temperature of 102° F., with an extremely tender mass in the right lower quadrant extending over the midline into the left lower quadrant, and marked muscle spasm and rigidity. The remainder of the physical examination contributed nothing significant.

Laboratory tests revealed occasional pus cells in the urine, 13.6 gm. of hemoglobin and 21,000 leukocytes, with a differential count of 88 per cent neutrophils, 1 per cent eosinophils and 11 per cent lymphocytes.

The diagnosis was a ruptured appendix and pelvic abscess which, at the time

of drainage, contained 6 to 8 ounces (180 to 240 cc.) of foul pus. The patient was dismissed on the eleventh hospital day.

One month later the patient returned for interval appendectomy. A draining sinus was present at the site of the old scar, and the patient had complained to her parents of vague abdominal pain on several occasions during her convalescence at home.

Appendectomy was performed in the usual manner and considerable inflammation in the ileocecal region was noted by the surgeon. The postoperative course was uneventful.

The pathologist reported that the appendix measured 5 cm. by 1 cm. and showed subacute appendicitis on a chronic appendicitis. The midportion was constricted with an overlying area of periappendiceal and chronic abscess formation at the site of previous rupture. Further examination with removal of a small amount of necrotic tissue from the involved area revealed a small diverticulum approximately 5 mm. in diameter. Grossly the diverticulum was very thin and no muscle was visible. Microscopically the findings were those consistent with a subacute inflammatory process, with scar tissue present at the site of previous perforation and absence of the mucosa at this site.

SUMMARY

The literature relevant to diverticula of the appendix, both congenital and acquired, has been reviewed. Forty-seven cases of proved ruptured appendicitis with abscess were studied to ascertain the clinical and pathologic characteristics of false diverticula. The incidence of false diverticula in previously ruptured appendixes was 74.4 per cent in this series. The average age of the patients who had diverticula was 28.6 years: the youngest was 2.5 years and the oldest 64 years. The ratio of males to females was 3:2.

In the total of 32 cases in which an appendiceal abscess had been drained previously and diverticula were found, the following conditions occurred: in 6 the appendix ruptured again with formation of a second abscess within an average of 4.5 months. Seven patients returned within an average of 3.2 months with acute symptoms. Including the appendixes removed at interval operation, 60 per cent of the patients showed either pathologic, or both clinical and pathologic evidence of recurrent inflammation in the appendix within an average of 4.5 months after the drainage operation.

There were no symptoms which could be referred directly to the presence of a false diverticulum of the appendix per se. After drainage of a primary appendiceal abscess, recurrent symptoms appeared to be more rapid and fulminating in nature, with secondary rupture occurring in a very short space of time.

The majority of the false diverticula were located along the mesenteric border (40 per cent), and 22.8 per cent were located on the antimesenteric border and the same number on the sides; in 14.4 per cent the site

could not be determined. These false diverticula were found most frequently (48.6 per cent) in the middle third of the appendix; the distal third contained 34.3 per cent, the proximal third 14.3 per cent and the site could not be determined in 2.8 per cent.

Microscopically the diverticula consisted of mucosa, submucosa, fibrous scar tissue and serosa. There was no muscularis present. Inflammatory changes were present to a varying degree.

Organic factors which probably gave rise to obstruction of the lumen of the appendix and hence increased intraluminal pressure, included fecalith in 7 cases, obstruction in 2, stricture proximal to diverticula in 2 and carcinoma in 1 case. A mucocele was noted in 1 case.

From this study it was concluded that false diverticula occur after perforation of the appendix. They represent an area of weakness in the wall of the appendix and are prone to re-infection.

Clinically they are important in the production of (1) early perforative appendicitis, (2) some cases of pseudomyxoma peritonaei and (3) granuloma formation in the ileocecal region. Interval appendectomy should be performed in all cases of perforative appendicitis which have been drained, as soon as the patient's condition warrants this procedure, preferably within two to three months.

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MULTIPLE POLYPS, MULTIPLE INTUSSUSCEPTIONS AND CHYLOUS ASCITES

Report of an Unusual Case

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In the case which forms the basis of this report, so many unusual features were manifested that we considered it worthy of discussion.

Two operations, performed on a young adult as emergency measures, revealed the following unusual features: (1) acute intussusception of the small bowel due to a large adenomatous polyp and another intussusceptive process within the first intussusception; (2) a second large polyp of the small bowel as well as diffuse polyposis of the entire colon and a third intussusception located in the sigmoid, and (3) acute obstruction and chylous ascites which were discovered on reoperation two months after successful subtotal colectomy for diffuse polyposis of the colon had been performed. The patient made a complete recovery from these complications and has remained well to the time of this report.

REPORT OF CASE

A white girl, 15 years of age, was admitted to the hospital on January 6, 1948, because of acute abdominal pain of twelve hours' duration. The pain was located in the periumbilical region, was cramplike and associated with persistent vomiting. Changes in bowel habit had not occurred. Pain and vomiting persisted and at the time she was admitted the tentative diagnosis of acute appendicitis was made.

The only significant fact in the patient's history was that she had been referred to the Mayo Clinic when six months of age because of prolapse of a mass from the anus. The mass proved to be a single rectal polyp which was subsequently fulgurated.

On examination the patient appeared to be experiencing a great deal of abdominal pain. Her general physical condition was good. There was no spasm or rigidity of the abdomen. A rather large abdominal mass, about 12 to 15 cm. in diameter, was palpated in the midabdomen. This mass was soft, moderately tender and easily movable. It could also be felt on rectal and vaginal examinations. Leukocytosis was manifested by a count of 21,500 leukocytes. Her temperature was 98.6° F. and results of urinalysis were negative.

Again a tentative preoperative diagnosis was made, this time of ovarian cyst on a twisted pedicle, and the patient was immediately prepared for operation. Exploration of the abdomen was performed through a low midline incision. A large, curved, sausage-shaped mass, smooth and shiny and covered with peritoneum was revealed lying free in the peritoneal cavity. Further examination proved it to be a curved, intussuscepted mass of jejunum 14 inches long with the

convex curvature lying well over the pelvic brim. The intussusception was slowly reduced by traction and milking. As the bowel was withdrawn from the intussusciens a second intussusception, 6 inches long, was found within the first and at the point of the second one, a large polyp was palpable through the wall of the bowel. The small bowel was then completely examined and a second polyp of moderate size was palpated in the jejunum 8 inches distal to the ligament of Treitz. No other polyps were felt in the small bowel or stomach. The colon was examined and multiple small polyps and a few moderately large ones were palpated within it. The beginning of a second intussusception was noted in the sigmoid. This was about an inch long and was due to a large polyp at this point. The two polyps were excised from the small bowel; fresh frozen sections showed evidence of low-grade adenocarcinoma (grade 1) in the tips of the polyps. The larger polyp measured 6 by 4 by 3 cm. and the smaller one measured 4 by 2 by 2 cm. The intussusception of the sigmoid was likewise reduced but the wall of the bowel was not opened. Ten grams of sulfathiazole and 100,000 Oxford units of penicillin were inserted into the peritoneal cavity.

The postoperative course was uneventful. On the ninth postoperative day, the patient had a proctoscopic examination which revealed 2 small polyps in the lower rectal segment. These were removed by fulguration and she was discharged on the eleventh postoperative day. In view of the diffuse polyposis of the entire colon the patient was advised to return to the clinic in a month for further surgical measures.

On February 27, after several days of preparation of the colon with sulfasuxidine administered orally, subtotal colectomy and end-to-side ileorectosigmoidostomy were performed. The pathologic report was as follows: "5 cm. of terminal ileum, cecum, appendix and 90 cm. of colon. The colon shows diffuse multiple polyposis, the largest polyp in the left colon measuring 4.5 cm. in diameter, and the second largest in the transverse colon measuring 4 cm. in diameter, and the third largest in the ascending colon 2 cm. in diameter. In addition to these, there are multiple (approximately twenty) polyps measuring from 3 to 1 cm. The largest three polyps mentioned show areas of low grade I adenocarcinoma." The patient made an excellent recovery from this operation and within three weeks from the time of her operation, she was having only two or three formed stools a day and maintaining her weight.

She enjoyed perfect health for six weeks after this operation. Then, on April 14, she was readmitted to the hospital because of acute crampy abdominal pain and vomiting. She described the pain as similar to that which she had had before her first operation. She had had a normal bowel movement two hours previously and blood was not present in the stool.

On admission the patient's temperature was 99.8° F., the pulse rate was 80, the respirations 20 and blood pressure 120 mm. of mercury systolic and 80 mm. diastolic. The abdomen was tense but not rigid. There were moderate distention and marked tenderness in the midabdomen and it was thought that a small soft mass could be palpated in this region. The leukocyte count was 15,000 and results of urinalysis were negative.

Because of the suspected mass in the abdomen and a history of multiple intus-

susceptions, it was thought that the patient had a recurrent intussusception and therefore immediate operation was decided upon.

Laparotomy revealed several loops of small bowel which were slightly dilated and somewhat cyanotic. The mesentery was edematous and the lacteals were noticeably injected, especially in the jejunal area where the lymph formed milky masses. There was approximately 500 cc. of white, milky fluid present in the peritoneal cavity. This substance was removed by suction and a specimen was analyzed for total fat content. Further investigation disclosed a thick adhesive band about $\frac{1}{4}$ inch wide which extended from the midmesentery of the proximal jejunum to the serosal surface of the terminal ileum. *This band was inflamed and it had constricted the base of the mesentery of the small bowel, somewhat blocking the flow of venous blood and evidently almost completely obstructing the flow of lymph. On section of this band, the entire small bowel promptly became pink.* The previously fashioned ileosigmoidal anastomosis seemed adequate.

Analysis of the milky fluid removed from the peritoneal cavity showed a fat content of 1,482 mg. of total lipids per 100 cc. which established the diagnosis of chylous ascites. The operation was performed and the patient's convalescence was uneventful. The patient has remained well to the time this report was written three months after operation.

COMMENT

Intussusception, when present in older children and adults, is almost always associated with some organic cause, as a rule a tumor of the wall of the bowel. Meckel's diverticulum, gunmas, ulcers of dysentery, typhoid and tuberculosis, parasites and foreign bodies also have been described as the cause of the type of intussusception common to adults. This is, of course, in marked contrast to the intussusception of infancy and childhood in which a definite etiologic factor usually cannot be predicated. In 17 per cent of Rankin and Newell's 35 cases of benign tumors of the small bowel, the lesions produced intussusception and intestinal obstruction. Joyce estimated that intussusception complicates about 30 per cent of all tumors of the small intestine.

Adenomatous polyps of the small bowel are uncommon. Botsford and Seibel in reviewing the clinical and necropsy records of the Peter Bent Brigham Hospital found a total of only 65 cases of primary tumors of the small bowel from 1913 to 1946. Only 5 of these were adenomatous polyps.

The combination of polyps of the small bowel and diffuse polyposis of the colon does occur, although it is unusual. Gerwig and Stone reported the case of a patient who had an acute jejunal intussusception and diffuse polyposis of the colon. C. W. Mayo stated that the stomach and small intestine were involved at the same time as the colon in about 5 per cent of the cases of diffuse colonic polyposis. He emphasized that

PROLAPSE OF THE RECTUM IN INFANCY AND CHILDHOOD

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The purpose of this study was to determine the prognostic significance of prolapse of the rectum in infants and children. Buie has emphasized the fact that, although rectal prolapse may generally be considered an affliction of childhood and old age, it occurs in all age groups. Our chief aim was to study whether a rectal prolapse in childhood might continue to be a clinical problem in adult life and whether the therapeutic measures indicated for this condition could be determined more clearly. Classification of the various types of rectal protrusion can be complex and confusing. Bacon distinguished the terms "prolapse" and "proci-dentia." He considered the former as a downward displacement of mucous membrane alone, and the latter as a downward displacement of all the coats of the rectum. For the sake of simplicity, we prefer to use the term "prolapse" in its broadest sense, making only an occasional distinction between "mucosal prolapse" and "complete prolapse."

ETIOLOGY

It is generally accepted that the anatomy of the pelvis and the rectum of the infant predispose to rectal prolapse. As summarized by Daniels, the shape of the pelvic bones, the flatness of the sacrum, the straightness of the rectum and the weakness of the lateral ligaments are factors which can readily permit protrusion of the bowel. Corbett stated that prolapse is an exaggeration of normal eversion of mucous membrane. Many authors, among them Alexander, Fraser, Gama and Norbury, have emphasized the fact that if there is maldevelopment or atony of the external anal sphincter, the likelihood of prolapse is enhanced. Mummery, in a search for the causative factors in 50 cases of prolapse in children emphasized the significance of malnutrition, because of the resultant loss of perirectal fat. Wiklander considered unfavorable social conditions as a contributory factor in many of the cases he has studied.

Moschcowitz is responsible for the widespread acceptance of the theory that a complete prolapse of the rectum is in reality a sliding hernia through the pelvic fascia. Pemberton and Stalker, in considering surgical therapy, concluded that an abnormal, loosely attached rectum is a most important predisposing factor.

The exciting causes of rectal prolapse are necessarily numerous. Anything which increases intra-abdominal pressure can be blamed for causing

the bowel to protrude. Straining may be the sequel of respiratory, urinary, or gastro-intestinal disease.

AGE INCIDENCE OF RECTAL PROLAPSE IN CHILDREN

The case records of 69 patients less than 15 years of age, who had rectal prolapse were studied. These patients were seen at the Mayo Clinic in the thirty years from 1918 through 1947. Of this group, 38 were males and 31 were females. Prolapse of the rectum had occurred when the patients were less than 3 years of age in a majority of these cases (table 1).

TABLE 1
AGE AT ONSET OF PROLAPSE OF THE RECTUM

Age at Onset	Cases
Less than 6 mo	10
6 to 12 mo	13
1 to 3 yr	30
4 to 6 yr	7
7 to 9 yr	2
10 to 15 yr	7
Total	69

CLINICAL FEATURES

It was difficult to evaluate the severity of rectal prolapse in these 69 children. In some cases the history given by the parents indicated that the degree of protrusion was greater than could be observed on admission. In the vast majority of cases, the protrusion was slight or moderate in degree and no more than 1 or 2 cm. of rectal mucosa was everted with each bowel movement. These prolapses would either recede spontaneously or reduce easily with gentle manipulation. In 13 cases (about 20 per cent) more than 4 cm. of mucosa protruded and it frequently was somewhat difficult to replace. In the severer cases the anal musculature was either poorly developed or the tone of the anal sphincter was less than normal.

Bleeding from the rectum which was noted in 24 cases (36 per cent) was usually slight. The amount or frequency of bleeding was usually in proportion to the severity of the protrusion. A history of constipation was obtained in 14 cases (20 per cent) and a history of diarrhea in 11 cases (16 per cent). These changes in bowel habit, however, could not be proved to be causative factors for the prolapse. A history of excessive straining while the child is on the toilet seat or the tale of a difficult battle over toilet training is probably a more important etiologic factor. Pain was rarely noted, and the reduction of the protruded mass was difficult. Proctoscopic examination of the rectum

usually revealed complete absence of other rectal disease. One child, aged 11 years, who had only a slight mucosal prolapse, suffered from anorectal ulcerations and polyps of the rectum; in this case the prolapse was a secondary problem. Another patient, 11 years of age, possessed small internal hemorrhoids.

DISEASES ASSOCIATED WITH RECTAL PROLAPSE IN CHILDHOOD

Associated conditions were diagnosed in many of the 69 cases of prolapse. The diagnoses are listed in table 2. Some of these obviously were the chief medical problems in the cases concerned. The simple listing of

TABLE 2

ASSOCIATED CONDITIONS IN CASES OF RECTAL PROLAPSE AMONG CHILDREN

Diagnosis	Cases
Exstrophy of urinary bladder	8
Mental retardation	8
Malnutrition	7
Congenital heart disease	3
Inguinal hernia	2
Celiac disease	2
Phimosis	2
Spina bifida	2
Epilepsy..	1
Convulsions (cause undetermined)	1
Pin worms	1
Cretinism	1
Megacolon	1
Rheumatic heart disease	1
Hay fever	1
Precocious menstruation	1
Pyelocystitis	1
Congenital urinary atony	1
Whooping cough with pneumonia	1
Diabetes	1
Anorectal ulceration	1
Rectal polyps	1
Total	48

these diseases gives some evidence that prolapse of the rectum is frequently found linked with other signs of constitutional inadequacy. It should be noted that although about 10 per cent of these children were undernourished, the remainder were usually in good physical condition.

TREATMENT

It is not the purpose of this study to discuss and recommend therapeutic measures in detail. Many therapeutic measures are recommended in the literature and excellent results are claimed for such procedures as submucosal or perirectal injections, cauterization and various types of

surgical procedures. It has been the policy of the members of the Section on Pediatrics of the Mayo Clinic to treat prolapse of the rectum in infants and small children conservatively. The usual program of conservative therapy consists of dietary management, with the use of mild laxatives, such as milk of magnesia as needed, to facilitate defecation and prevent straining at stool. A toilet seat with a small opening which compresses the child's buttocks is advocated and parents are instructed to reduce the prolapse promptly when it occurs. Occasionally it may be necessary to strap the buttocks for a short period.

Radical measures have been resorted to in only a few cases, and then only if the child had marked complete prolapse. In these cases an abdominal operation of the Moschcowitz or the Pemberton type has been the procedure of choice. In 1 case perirectal injections of 5 per cent solution of sodium psylliate gave a good result.

FOLLOW-UP STUDIES

Since most of the patients seen at the clinic had been treated conservatively, we attempted to follow them up with the dual purpose of determining the prognosis of rectal prolapse in children, and re-evaluating our therapeutic approach to the problem.

Follow-up data in 40 of the 69 cases of rectal prolapse are presented in table 3. Only cases in which the condition of the prolapse could be followed for two or more years were included. The information was obtained from subsequent examinations at the clinic or by the answers to questionnaires sent to the patients who had been to the clinic as children and did not subsequently return. The age recorded in cases in which the prolapse underwent remission is that given by the patient as the first year in which there was no further protrusion. Otherwise the oldest known age at which the individual did or did not have a prolapse is recorded.

In a few instances (cases 1, 2 and 3) the prolapse was evident in the first months of life and may be assumed to be congenital in nature. The association with other congenital defects, such as spina bifida and exstrophy of the bladder was evident. The gravity of the therapeutic problem involved in cases of exstrophy relegates the rectal prolapse to a position of minor importance.

Twenty-five patients whose age of onset was between six months and three years were treated conservatively and after variable periods of time, prolapse ceased to occur. It is interesting to note that spontaneous remission usually occurred sometime before or during the sixth year of life. Once the condition is outgrown, we have no evidence that it will recur in later childhood or adult life.

Case 15 in which prolapse began at the age of 1 year, illustrates the

TABLE 3
COURSE IN 40 CASES OF RECTAL PROLAPSE IN CHILDREN

Case	Sex	Age at Onset	Degree of Protrusion	Treatment	Spontaneous Remission or Surgical Cure		Rectum Still Prolapsed at Age, yr.	Remarks
					Age, yr.*	No Prolapse Reported at Age, yr.†		
1	F	1 mo.	Slight	Conservative			26	Spina bifida
2	F	2 mo	Severe	Abdominal surgery			4	Exstrophy of bladder
3	M	2 mo	Moderate	Conservative			5	Spina bifida
4	F	2 mo	Slight	Conservative	3 mo.	5		
5	F	3 mo.	Slight	Conservative		8		
6	M	6 mo	Slight	Conservative		3		
7	F	6 mo	Moderate	Conservative	1½	2½		Exstrophy
8	F	6 mo	Slight	Conservative		4		Exstrophy
9	F	6 mo.	Slight	Conservative		30		
10	M	1 yr	Slight	Conservative	6	13		
11	M	1 yr	Slight	Conservative	5	15		
12	M	1 yr.	Severe	Conservative	6	8		
13	F	1 yr.	Slight	Conservative	1	4		Exstrophy
14	M	1 yr.	Moderate	Conservative	6	7		Phimosis
15	M	1 yr.	Severe	Surgery (Moschcowitz) at age of 11			13-19	Operated on elsewhere at age of 19 yr.
16	M	1½ yr.	Moderate	Conservative		13		
17	F	1½ yr	Slight	Conservative	4	7		Mental retardation
18	M	1½ yr.	Slight	Conservative			4	Exstrophy of bladder
19	F	1½ yr	Slight	Conservative	9	11		
20	M	1½ yr.	Moderate	Conservative		5		Inguinal hernia
21	M	1½ yr.	Slight	Conservative	4	12		
22	M	2 yr.	Severe	Surgery	5	28		

TABLE 3—Continued

Case	Sex	Age at Onset	Degree of Protrusion	Treatment	Spontaneous Remission or Surgical Cure		Rectum Still Prolapsed at Age, yr	Remarks
					Age, yr.*	No Prolapse Reported at Age, yr.†		
23	F	2 yr	Slight	Conservative	6	17		
21	F	2 yr.	Slight	Conservative	5	6		
25	F	2 yr	Slight	Conservative	3	19		
26	F	2½ yr	Severe	Injections	4½	12		Cretinism
27	M	2½ yr	Slight	Conservative		10		
28	F	2½ yr	Slight	Conservative	6	20		
29	M	2½ yr	Slight	Conservative	7	16		Mental retardation
30	F	3 yr	Slight	Conservative	4	26		
31	M	3 yr	Slight	Conservative		10		
32	F	3 yr	Slight	Conservative	4	19		Diabetes
33	M	3 yr	Severe	Conservative			17	Surgery advised at 8 yr; not done
34	F	4 yr	Slight	Conservative	6	10		
35	F	4 yr	Slight	Conservative			10	
36	F	5 yr	Moderate	Conservative			13	Surgery advised elsewhere
37	F	7 yr	Moderate	Conservative			11	Mental retardation
38	M	10 yr	Severe	Surgery	10	36		
39	M	11 yr	Moderate	None			31	Injections advised, not done
40	F	13 yr	Severe				19	Operated on elsewhere

* Age reported by patient as onset of remission

† Oldest known age at which patient did not have prolapse

fact, however, that instead of subsiding, the condition may become increasingly severe. In this instance the child underwent a Moschcowitz operation at the clinic at the age of 11 years, but the prolapse recurred when he was 13 years old. It was treated surgically elsewhere when he was 19 years of age.

The prognosis for children whose symptoms of protrusion first appeared after they were 4 years old was gloomier. In only 1 case (case 34) was conservative therapy successful. In all the other cases the prolapse persisted. These older children had prolapses which were complete in type. Although surgical treatment was advised for most of the older children, it was performed in only 1 case (case 38).

Since prolapse of the rectum of 5 of these 40 patients persisted until they were beyond the age of 17 years, it may be estimated that in at least 10 per cent of cases occurring in childhood the prolapse of the rectum will continue into adulthood.

TABLE 4
AGE AT TIME OF EXAMINATION AND AT ONSET OF RECTAL PROLAPSE IN 100 CASES
AMONG ADULTS

Age, yr.	Patients
At examination	
20-40	34
41-60	48
61-80	18
At onset	
Childhood	14
10-20	15
21-40	34
41-60	24
61-80	13

AGE OF ONSET OF RECTAL PROLAPSE IN ADULT PATIENTS

Since it is evident that in some cases rectal prolapse will persist from childhood into adult life, an attempt was made to corroborate the evidence obtained from the cases of children with further study of case records of adult patients who had rectal prolapse. One hundred consecutive cases of adults were selected who, at the time of their first examination were more than 20 years of age, and who had a demonstrable complete prolapse of the rectum. Fifty-one of these patients were women and 49 were men. Their ages at the time of examination are given in table 4.

By examining the records to determine the duration of symptoms and the approximate age at onset of symptoms, it was found that many of these patients had suffered from prolapse for many years before examination or treatment. The age at onset in these same cases is given in table 4 also.

As would be expected, few of these patients could give the exact age

at which prolapse was first noticed, but several of the 14 patients thought that the trouble began around the age of 4 years. Without being dogmatic about percentages it was apparent that a substantial number of the rectal prolapses seen in adults began at an early age.

SUMMARY

Study of 69 cases of prolapse of the rectum among children disclosed that prolapse of the rectum may occur at any age from birth on, and continue into adult life. Roughly, in at least 10 per cent of all cases, the rectal prolapse may persist beyond childhood.

One hundred consecutive cases of complete rectal prolapse among adults were studied also. The records of 14 of these 100 indicated that the trouble began sometime during childhood.

Our studies indicate that the great majority of infants from the ages of 6 months through 3 years who have rectal prolapse will respond to conservative therapy. In these cases prolapse seldom continues after the age of six. When rectal prolapse occurs in children older than five years, it is usually of the complete type and should be treated as in adult cases.

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MULTIPLE PRIMARY TUMORS OF THE SPINAL CORD

Report of Case

HENDRIK J. SVIEN, JOHN D. CAMP AND ALFRED W. ADSON

DR. SVIEN: The purpose of this paper is to report the case of a patient who has had three primary neoplasms of the spinal cord removed successfully.

REPORT OF CASE

The patient, a white married woman, 29 years of age, first registered at the Clinic on March 29, 1935. Her presenting complaint was difficulty in walking for three years. Prior to the onset of this complaint she had enjoyed good health. Her family history was noncontributory. Three years prior to admission she had had an attack of acute tonsillitis. Following this attack she noticed some swelling of the ankles and stiffness of the knees. Some weeks later she first noticed that she stumbled easily if she did not observe her feet when she walked. Intermittent sensations of numbness, tingling and prickling were present in her feet and were most pronounced in the right foot. Acuity of touch and of temperature discrimination were diminished on the lower part of the trunk and both lower extremities. Several weeks after the onset of these sensory symptoms, she noticed progressive weakness of both legs, which was more marked on the right side. For two years prior to admission she had had occasional urgency of urination and urinary and rectal incontinence. For one year prior to admission she had had episodes of sharp shooting pain in her legs which were more severe in the right leg. For six months prior to admission, jerking movements had occurred occasionally in her legs.

Examination revealed a fusiform mass in the right superior carotid triangle beneath the sternomastoid muscle. The mass measured 5 by 10 cm. and moved with the larynx on swallowing.

Neurologic examination revealed bilateral spastic paraplegia; the spasticity was more pronounced on the right side than on the left. Muscle strength in the right leg was graded -3 and in the left leg -1, on the grading basis of -1 to -4. Vibration sense and joint sense were markedly diminished, from the level of the fifth thoracic dermatome downward. Sensations of pain and touch were moderately diminished in this same region. The deep tendon reflexes were exaggerated in the lower extremities. The abdominal reflexes were absent. The tone of the anal sphincter was decreased. Kernig's and Lasègue's signs were positive.

Spinal puncture was performed. The initial pressure of spinal fluid was 12 cm. of spinal fluid. On bilateral jugular compression, the pressure rose to 36 cm. Within the next ten seconds it fell to 34 cm. and remained there for the next ten seconds. These findings indicated the presence of a subarachnoid block. The spinal fluid was xanthochromic. Analysis revealed a total protein content of 280 mg. per 100 cc. with 3 lymphocytes per high-power field. A diagnosis was made of tumor of the spinal cord at the level of the fourth and fifth thoracic vertebrae.

The patient was informed of the presence of the two surgical lesions. In view of the marked evidence of involvement of the spinal cord, she was advised to have the tumor of the spinal cord removed first and then later, during convalescence, to have the mass in the neck removed.

Accordingly on April 5, 1935, with the patient under intratracheal nitrous oxide, carbon dioxide, oxygen and ether anesthesia, laminectomy was done at the level of the fourth and fifth thoracic vertebrae. When the dura was opened, a mass, measuring 2 cm. in length and 1.5 cm. in its transverse aspect, was exposed. It was attached to the dorsolateral aspect of the dura on the left side. The cord adjacent to the tumor was compressed to about two-thirds normal size, but otherwise appeared normal. Grossly the tumor was diagnosed as a meningioma. The involved dura was excised together with the tumor mass. The defect in the



Fig. 453—Intradural, extramedullary meningioma of the spinal cord removed in 1935.

dura was closed with animal membrane. Microscopic examination confirmed the diagnosis of meningioma (figs. 453 and 454).

Postoperatively the patient's course was uneventful. On the eighth postoperative day, the tumor in the right side of the neck was removed. It was attached to the superior sympathetic ganglion. Microscopic study revealed the tumor to be a neurofibroma.

Neurologic examination at the time of dismissal revealed considerable improvement in the motor power of the lower extremities and some improvement in the sensory sphere also.

The patient returned to her home and improved rapidly. Seven months after removal of the tumor of the spinal cord, she wrote that she walked almost normally and that she was able to do her own housework. She continued to improve steadily and enjoyed a normal, full existence for the next twelve years. During this period, she was delivered, uneventfully of two normal infants, the first in

1939, and the second in 1944. She also underwent an operation for uterine suspension, without incident, in 1939.

On October 5, 1948, the patient registered at the Clinic. She stated that in 1943 she first noticed intermittent bilateral tinnitus and some degree of deafness in the left ear. In July, 1947, she first experienced stiffness in her neck on arising in the morning. The onset of this symptom was followed by numbness in her right hand. The stiffness of the neck increased and was associated with pain. The pain became progressively worse and spread to involve the occipital region and both shoulders. This pain was initiated or aggravated by lying down, and was some-

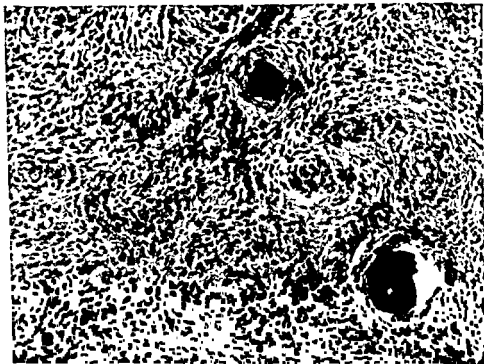


Fig. 454—Psammomatous meningioma; section from tumor shown in figure 453 (hematoxylin and eosin $\times 150$).

what relieved by assuming the upright position. In March, 1948, seven months prior to her second admission, she noticed a sensation of numbness in both legs. At this time also she began to experience some difficulty in walking; this consisted chiefly of stumbling. She also experienced intermittent cramping in the right leg. In September, 1948, one month prior to her second admission to the Clinic, she began to have some difficulty in starting urination.

From the evidence obtained at the second examination, and from the findings on the previous visit, a diagnosis was made of von Recklinghausen's disease with multiple lesions of the central nervous system.

Several subcutaneous nodules were present at various places over the body. Neurologic examination suggested the presence of at least two lesions of the central nervous system: (1) a tumor of the left cerebellopontine angle, and (2) a lesion of the spinal cord in the cervical region.

The corneal reflex on the left was diminished (-1). The degree of variation from normal is indicated by a basis of 1 to 4, the $-$ sign indicates reduction and $+$ sign an increase. Auditory acuity on the left was markedly diminished. Motor power in the right shoulder, arm and hand, from the level of the supraspinatus muscle down was slightly reduced (-1). The deep tendon reflexes were equal, but were somewhat hyperactive ($+3$). The Babinski sign was present bilaterally.



Fig 455—Myelographic findings with radiopaque oil in 1948 *a*, Complete subarachnoid block is present at level of fourth cervical vertebra *b*, Partial block is present at level of interspace between first and second lumbar vertebrae

The abdominal reflexes were absent on the left and markedly diminished on the right. In both hands touch perception was diminished, diminution of -2 was present on the right and -1 on the left. Joint sense was also diminished -2 in the fingers of the right hand. In both lower extremities, from the level of the knee joint down, touch and perception of pain were diminished somewhat (-1). Vibratory and joint sense were markedly diminished (-3), bilaterally in these same regions. Her gait was spastic ($+2$) and ataxic ($+2$).

Roentgenographic examination of the cervicothoracic portion of the spinal column revealed nothing of significance except for the defect due to the previous laminectomy. Roentgenograms of the skull and the special views for the internal acoustic meatuses (Stenver's position) were not contributory.

Myelography with iodized oil was carried out. The initial pressure of spinal fluid was 16 cm. of spinal fluid. When bilateral jugular compression was maintained for ten seconds, the column of spinal fluid rose to 65 cm. During the next ten seconds, it fell to 45 cm. and during the following ten seconds, it fell to 34 cm. These findings indicated a partial subarachnoid block. Five cubic centimeters of iodized oil was then introduced into the spinal subarachnoid space. Roentgenoscopic examination revealed a complete block to the cephalad flow at the level of the fourth cervical vertebra. The filling defect was typical of that produced by an intradural, extramedullary mass. In addition to this finding, another lesion, which had not been suspected from the clinical findings, was uncovered by myelography. The cephalad flow of iodized oil was partially arrested at the level of the interspace between the first and second lumbar vertebrae. The defect at this level was also typical of an intradural, extramedullary lesion (fig. 455, *a* and *b*).

Removal of the tumors of the spinal cord was advised. The patient also was told of the possibility of a tumor of the cerebellopontine angle on the left. Inasmuch as the symptoms and signs referable to the cerebellopontine angle were minimal, decision regarding further investigation and possible operation for this lesion was deferred until later.

Accordingly, on October 16, 1948, laminectomy of the third, fourth, and fifth cervical vertebrae was carried out. An intradural, extramedullary tumor arose from the anterior root of the fifth cervical nerve on the left, but presented on the right anterolateral aspect of the cord. The tumor which measured 1 cm. in diameter had compressed the adjacent spinal cord to half its normal size. The tumor was completely removed and proved on microscopic examination to be a neurofibroma (figs. 456 and 457).

The patient's convalescence following this procedure was uneventful. Twelve days following cervical laminectomy, lumbar laminectomy centered over the interspace between the first and second lumbar vertebrae was carried out. A tumor which was attached to the posterior root of the fourth lumbar nerve on the right was found. It measured 1.5 cm. in diameter. This tumor was extirpated, and on microscopic examination proved to be a neurofibroma.

Results of neurologic examination on November 17, 1948, one day before dismissal from the hospital, were essentially the same as the preoperative examination. The pain which had been present in the cervical region on admission had disappeared. In a letter written two and a half months after dismissal, the patient stated that she was able to do most of her housework, and that she no longer had urinary incontinence or bladder difficulty.

Multiple primary tumors of the spinal cord and its meninges are rare, and until the introduction of myelography were usually found accidentally at necropsy. They are most frequently found in association with certain conditions which characteristically present other abnormalities or stigmas. In von Recklinghausen's disease, multiple neurofibromas

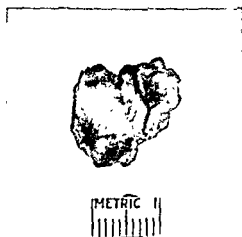


Fig 456—Intradural, extramedullary tumor of the spinal cord removed from cervical region in 1948

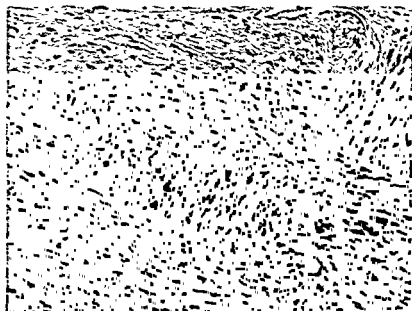


Fig 457—Neurofibroma, section from tumor shown in figure 456 (hematoxylin and eosin $\times 125$)

alone may be present in the spinal cord, or various combinations of neurofibroma, meningioma and glioma may be present. In Lindau's disease, multiple hemangioblastomas are occasionally found in the spinal

cord. Multiple ependymomas have been described, frequently in association with syringomyelia. Multiple meningiomas have been reported; in the case of Marinesco and Goldstein they were associated with multiple intramedullary ependymomas. To a miscellaneous group may be added the multiple lipomas of the spinal cord which are usually extradural, the multiple spinal osteomas, and the multiple dermoid cysts of the spinal cord and meninges.

Our surgical cases of multiple primary tumors of the cord, and those reported in the literature can be divided into two groups: 1. Those in which the multiple tumors are aggregated closely at the same level of the spinal cord. Examples of this group are the cases in which a single nerve root harbors several neurofibromas. Clinically these multiple lesions produce signs and symptoms which are indistinguishable from those produced by a single lesion. Only by the aid of contrast myelography can the multiple nature of such lesions be determined pre-operatively. 2. Those cases in which the multiple tumors are present at distinctly different levels of the spinal cord. Our case is illustrative of this group. The tumor at the higher level of the spinal cord will generally produce clinical signs and symptoms which mask those which are produced by the tumor at lower levels of the spinal cord. In other instances the multiple new growths may produce a clinical picture suggestive of a disseminated lesion of the spinal cord, such as multiple sclerosis. Here, again, contrast myelography is of invaluable aid in revealing the true nature of the disturbance.

Three salient points stood out from the review of this case. 1. Multiple tumors of the spinal cord, although rare, do occur. It behooves physicians who deal with lesions of the spinal cord to be constantly mindful of this fact, and to be ever suspicious of the possibility of the presence of multiple tumors. 2. A patient who has multiple tumors of the spinal cord can be successfully treated and restored to normal living by judicious surgical procedures. 3. Contrast myelography is an invaluable aid in the diagnosis of multiple tumors of the spinal cord.

DISCUSSION

DR. CAMP: The ability to recognize multiple tumors of the spinal cord before operation is just one of the contributions of myelography to the modern precise location of neurologic lesions. In 1936 when I first reported my experience with multiple tumors of the spinal cord, it was found that 4 per cent of tumors that were localized by myelography were diagnosed as multiple tumors by the radiologist and in all cases the diagnosis was confirmed at surgery.

For roentgenologic consideration multiple tumors of the spinal cord may be classified as follows:

- I. Multiple tumors arising from the same nerve
 - A. Neurofibromas
 - B. Neurofibromatosis
- II. Multiple discrete unrelated tumors
- III. Protruded disk and tumor
- IV. Multiple protruded disks

Multiple Tumors Arising From the Same Nerve.—The classical example of this tumor is the neurofibroma which may be revealed as two or more nodules arising from various points along the same nerve root. Some of these nodules may be intradural, others extradural, and some of the extradural nodules may even extrude through the intervertebral foramina. The defect observed in the myelogram will depend on the size and position of the tumors.

In neurofibromatosis there is a combination of multiple tumors of numerous nerve groups which result in a multiplicity of defects in the myelogram.

Multiple Discrete Unrelated Tumors.—The most common tumors in this group are the multiple meningiomas which arise independently in various regions of the spinal canal and multiple neurofibromas. The latter, although they may be a part of the generalized condition of neurofibromatosis, in this instance grow as a single discrete tumor of various nerve roots. The case presented herein is an example of tumors of this type.

Protruded Intervertebral Disk and Intraspinal Tumor.—Cases in this group are those in which one or the other lesion, usually a protruded disk, is suspected, and both conditions are found to be present by myelography. In all cases of this group in which we have made observations at the Clinic the lesions were separated from each other by two or more segments. It is in this group that myelography is of great value because a tumor in the upper part of the lumbar, and occasionally in the lower part of the thoracic, region may give rise to symptoms that imitate those resulting from a protruded intervertebral disk in the lower part of the lumbar region. This group also illustrates the importance of using an adequate amount of contrast medium (5 to 6 cc.) and carrying the myelographic study at least to the level of the eighth thoracic vertebra in all cases in which a protruded lumbar intervertebral disk is suspected or found.

Multiple Protruded Intervertebral Disks.—In about 18 per cent of all cases of protruded intervertebral disks these lesions are multiple. Myelography is the only practical method by which they may be diagnosed

and accurately localized prior to operation. They may involve contiguous intervertebral spaces or scattered intervertebral spaces. In one instance that we have observed the protruded intervertebral disk between the third and fourth lumbar vertebrae presented on the left side and a second protruded intervertebral disk at the lumbosacral junction presented on the right side. Both of these protrusions were confirmed at operation. It is obvious that unless the presence of multiple protruded intervertebral disks is recognized prior to surgery, a limited laminectomy may not reveal the multiple protrusions. Under such circumstances the postoperative result may not be all that is desired.

The mere fact that multiple tumors may exist within the spinal canal would seem reason enough to discourage the use of small, inadequate amounts of contrast media and limited fluoroscopic investigations. If there is evidence enough to justify the use of myelography certainly sufficient media and a fluoroscopic investigation comprehensive enough to insure the highest efficiency of the examination are indicated. The case presented by Dr. Svien clearly supports this attitude.

DR. ABSON: In view of the fact that this patient has had several neurofibromas I presume that her disease should be classified as von Recklinghausen's disease. There are, however, two unusual findings in her case. The first is that one of the intraspinal tumors was proved to be a meningioma. The second is that the intraspinal neurofibromas are associated with only one obvious neurofibroma of a peripheral nerve. In all probability, another tumor is developing in an acoustic nerve.

Two lessons may be learned from a study of this case. The first is that the symptoms produced by the tumor situated at the highest level may obscure those produced by the tumor or tumors at lower levels. In this particular case, the myelographic study revealed the two intraspinal tumors. The second lesson is that when a neurofibroma of the spinal canal has been found, there is always a possibility that others may exist even though they occur but rarely. Dumb-bell neurofibromas occur rather frequently. When they develop one portion is situated within the spinal canal and the other on the outside of the spinal column. The two portions are connected by a cord of tumor tissue within the spinal nerve as it passes through the intervertebral foramen.

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LIPOMA OF THE COLON

GABE C. LONG, MALCOLM B. DOCKERTY, AND JOHN M. WAUGH

Lipomas of the gastro-intestinal tract were formerly looked upon by many investigators as being pathologic curiosities of little importance, and consequently in most standard textbooks of medicine and surgery one finds very few paragraphs devoted to this subject. Because of this undeserved obscurity and the atypical clinical picture which these tumors produce, the preoperative diagnosis is seldom made and the treatment instituted is not always the most desirable. It is now recognized that they occur frequently enough to be considered in the differential diagnosis of intraabdominal tumors and in the establishing of a positive causative factor not only in certain common intestinal conditions, such as intestinal obstruction and intussusception, but also in obscure intestinal disorders productive of bleeding. Lipomas, if adenomas are excluded, are the most common benign tumors of the colon.

HISTORICAL DATA

As early as 1757, in his "*Epistola de Mois Intestinorum*," Bauer recorded accounts of intestinal lipomas. Comfort cited Cruveilhier as one of the first to mention the existence of lipomas of the gastro-intestinal tract. Hiller in 1899 made one of the first studies on these lipomas at which time he reviewed 23 cases. A number of accounts of lipomas of the colon are found in the literature, notably those of Stetten in 1909, Odelberg in 1921, Thorek in 1923, King in 1917, Wakeley and Paul in 1931, Comfort in 1931, Poston in 1934, Kirshbaum in 1935, Pemberton and McCormack in 1937, Gault and Kaplan in 1941, and Schottenfeld in 1943. Three or four of these reviews were comprehensive and are deserving of more than passing notice.

Stetten in 1909 found reports of 72 cases of gastro-intestinal lipoma, of which 32 were lipoma of the colon. Comfort in 1931 reviewed the subsequent literature and referred to 28 additional cases, including 3 surgical and 25 necropsy cases, making a total of 181 cases. Of these, 92 were cases of lipoma of the colon, 65 of the small bowel and 22 of the stomach. He emphasized the tendency of these tumors to cause intussusception.

By 1934, Poston was able to assemble reports of 242 cases of gastro-intestinal lipoma. Pemberton and McCormack in 1937, in their comprehensive review of lipoma of the colon, reported 3 "clinical" cases, bringing the total of clinical cases to 97, and said that the lipoma had been

thickness The submucosal growths are covered by the mucosa and occasionally by the muscularis mucosae while the subserous variety lies directly under the peritoneum. In each case, the covering constitutes the area of least resistance, as the underlying muscular layer forces the growth toward the intestinal lumen or the lumen of the peri-



Fig. 458—Pedunculated intussuscepting submucous lipoma of the ascending colon showing partial necrosis and superficial ulceration

toneal cavity respectively. The submucosal polypoid or pedunculated growth usually originates as a small infolding of mucosa occurring about a small cluster of fat cells, or as a minute lipoma which herniates between the infoldings. The passing intestinal content forms a constant force which, with the peristaltic wave, pulls and draws on the base until the pedicle is formed. The pedicle may vary from a thick cord to a tiny thread with a short stubby base or one with a base that is many centimeters in width. They are firm, elastic, rounded and usually multiloculated growths which are frequently covered by a visible fibrous con-

nective tissue capsule from which arise septa of varying thickness that divide them into lobules. If the connective tissue predominates in the tumor, it is termed a "fibrolipoma." The outer surface is frequently ulcerated and the underlying tissue reddened as a result of infarction and secondary inflammatory change. The consistency of the cut surface is that of normal fatty tissue, but secondary changes of inflammation or fibrosis may alter it. Constriction of the pedicle may produce spontaneous atrophy or cause spontaneous expulsion from the bowel. The usual color is that of normal fatty tissue; xanthomatous changes may yield an orange-yellow tint, and various other secondary processes may give corresponding spectral alterations.

The chief sites of origin in the present series were cecum, sigmoid flexure and hepatic flexure in the order named. In Pemberton and McCormack's review of the literature they found 50 tumors that arose in the right half of the colon, 15 in the transverse colon and 37 in the left

TABLE 1
GROSS PATHOLOGIC FEATURES OF LIPOMA OF THE COLON

	Cases
Size, cm.	1
Submucous	31
Subserous	2
Pedunculated	31
Sessile	2
Intussusception	10
Ulceration	20

half of the colon and the rectum. The size of the tumors varied from 1 to 9 cm. in diameter and the shape varied with the size of the tumor and the type of attachment.

The gross pathologic features are noted in table 1. The mucosa may retain its normal yellowish appearance or vary from normal to a reddish black or even black. It may be thin and atrophic, ulcerated or even necrotic. There were 31 tumors of the submucosal variety, 5 of these having a normal healthy yellowish mucosa, 15 having a dark discoloration of the dome and 20 showing ulcerations. There were only 2 cases of the subserosal variety, in both of which the symptoms produced were primarily the result of pressure on neighboring structure by a palpable tumor. In the submucosal variety the muscularis mucosae was very thin in the larger tumors, allowing the yellow color to be readily seen.

Microscopically the structure resembles normal fatty tissue but the lobules vary greatly in size and the supporting structure is irregular in distribution. Erosion of the dome with degenerative changes may occur, or hemorrhage may occur with areas of fatty degeneration, cellular in-

filtration and edema (fig. 459). Thrombosis and infarction may occur in some of the pedunculated forms, producing cystic degeneration, necrosis, ulceration or sloughing of the lipoma. In the sections of the submucous variety taken at the angle of the tumor origin, the mucosa is seen to surround the tumor but the muscularis fades out near the base. The mucosal covering is thin and atrophic and the muscularis mucosae



Fig. 459—Submucous lipoma of the colon illustrating hemorrhagic infarction of the overlying epithelium (hematoxylin and eosin $\times 32$).

TABLE 2
MICROSCOPIC FEATURES OF LIPOMA OF THE COLON

	Cases
Muscularis thickened	21*
Inflammation and edema	21
Infarction and hemorrhage	4
Necrosis and degeneration	16
Increased fibrosis	28
Increased cellularity	31

* Marked in 10 cases

barely perceptible. Table 2 is a summary of the microscopic features of the tumors studied in this series.

Symptoms.—There is no clinical syndrome which is pathognomonic of gastro-intestinal lipoma. The chief symptoms are those of intestinal obstruction produced by the tumor itself or by intussusception. All varieties of obstruction may be met with: acute, subacute, chronic, acute exacerbation of a chronic obstruction, partial, complete, intermittent

or progressive. The symptoms may be preceded by months or years of abdominal complaints of a vague or mild nature.

The size, location and behavior of the tumor determine the time of onset of symptoms which are mainly due to a combination of a number of effects secondary to the presence of the growth, namely, disordered peristaltic activity owing to the interference with the intrinsic nervous mechanism of the bowel wall, intussusception and obturation of the lumen. In addition, ulceration of the mucosal surface with or without hemorrhage, circulatory injury incidental to powerful peristalsis or intussusception with edema, congestion, infarction, necrosis and gangrene mark the onset of symptoms.

Clinically, the cases may be classified in three groups on the basis of symptoms. In the first group there are only vague intestinal complaints and the tumor is found only because of a complete examination including roentgenograms of the colon. In the second group there is a history of long-standing and gradually increasing constipation with recurring attacks of colicky abdominal pain, often associated with nausea and vomiting. This group comprises the cases in which there are recurrent, mild intestinal obstruction and recurrent intussusception. The symptoms are frequently noted after ingestion of bulky foods, often occur in episodes months to years apart and persist for a matter of hours to days. They may terminate with the passage of bloody stools. Between the attacks the patient is comparatively comfortable except for increasing constipation. The average duration of symptoms as computed by Pemberton and McCormack was 41.5 months, and in the present series 38.4 months.

A typical attack in the second group is characterized by intermittent abdominal distress, colicky pains and moderate abdominal distention with nausea and often vomiting; these attacks, too, are often terminated by bowel movements which occasionally may be bloody. It is likely that the early symptoms occur when the tumor is small owing to its encroachment on the bowel lumen with tension on its wall. As the attacks become more severe, an intussusception occurs which is difficult to reduce. There were 24 cases of this type in the present series.

In the third group are the cases of more severe intestinal obstruction. The clinical picture is more acute and intussusception is more frequently present than in the other groups. This picture was noted in 7 cases in the present series. The symptoms are of a few days' or few weeks' duration, and owing to the similarity of the picture to that of the acute obstruction seen with carcinoma, the diagnosis is frequently that of carcinoma. There may be a history of chronic recurrent attacks preceding the severe acute attacks. Apparent good health is usually present immediately before the onset. The attack of acute obstruction starts as a sudden, sharp, cramplike abdominal pain which is usually located in

the region of the tumor; nausea, vomiting and abdominal distention are present if the obstruction persists for many hours.

Pain is the main symptom which brings the patients in search of relief. In the present series it was the outstanding symptom in 25 cases and was of a colicky nature in 10 of these. Six patients complained primarily of a vague abdominal discomfort. On the average, attacks of pain had occurred for 3.2 years. The duration varied from one month to fifteen years. Constipation was present in 14 cases and diarrhea, either alone or associated with the constipation, was noted in 12 instances; melena, associated with one or the other, but usually with diarrhea, was seen 11 times. Nausea and vomiting were present in only 4 cases. These aforementioned chief intestinal symptoms were often incited and aggravated by taking food and relieved by a bowel movement. Anemia was present in 8 cases and weight loss and cachexia occurred in 11 cases. It is interesting, however, that the profound anemia seen in carcinoma of the cecum was not observed in cases of ulcerating lipoma of the cecum.

In 17 cases a palpable mass was noted either upon rectal examination or through the abdominal wall. In 4 of these cases carcinoma was associated with lipoma. In 1 instance a lipoma of the sigmoid was palpated in the pelvis by bimanual examination. In several instances a mass noted secondary to intussusception was found to disappear after a bowel movement. Positive roentgenologic evidence was present in 28 cases.

Diagnosis.—Because of the rarity of colonic lipoma a positive pre-operative diagnosis is seldom made. With this possibility in mind, however, the eliciting of a "typical" history, the finding of a palpable mass and the discovery by roentgen rays of an encapsulated submucosal lesion should suggest the possibility of a lipoma. A specific diagnosis of lipoma was made once in this series, but in 2 cases the roentgenologic report mentioned the likelihood that lipoma was present. Many roentgenologists feel that the mucosal pattern given by a benign tumor is of great help in identifying it. A diagnosis of "polypoid lesion," "intussuscepting lesion" or just "lesion" of the specific part of the large bowel was made in 10 other cases. On 14 occasions the roentgenologic diagnosis was "carcinoma of the colon." Some men believe that the existence of lipomas elsewhere in the patient should aid in diagnosis of lipoma of the bowel.

Ordinarily it is not possible to distinguish roentgenologically between the various histologic types of polypoid neoplasms. It is known, however, that adipose tissue, whether of neoplastic origin or not, is the most radiolucent of all body tissues. Accordingly, it has been thought that with the use of the double contrast method in the roentgenologic examination of the colon, it is possible to suspect the true histologic nature of some of the lipomas encountered, by noting their failure to manifest

the primary density possessed by intraluminal tumors of other histologic types.

When a lipoma is seen through a proctoscope, its soft lobulated consistency and the yellow tinge of the mucosa overlying the tumor may lead to the correct diagnosis, but the changes secondary to a vascular disturbance frequently alter the appearance of the lesion.

With acute symptoms of short duration, it may be difficult to distinguish the true situation from acute appendicitis, especially when the lipoma involves the cecum and ascending colon. In most cases, as shown by previous records, the preoperative diagnosis is that of recurrent partial obstruction of the bowel, and the presence of a tumor is rarely suspected.

Treatment.—Treatment for this condition is strictly surgical, but the co-operation of the internist in the preoperative management is necessary in some cases. Those patients with acute obstruction should undergo decompression and other supportive measures should be instituted before an operation is performed. Local enucleation or segmental resection with an end-to-end anastomosis is the procedure of choice when the patient has been properly prepared and the risk is not great. In some cases in which preparation with a nonresidue diet, sulfasuxidine, irrigations and decompression is not accomplished, a two-stage procedure may be required. This may necessitate a proximal colostomy or cecostomy, or a modified Mikulicz type of procedure. On the right side of the colon a right hemicolectomy with an ileotransverse colostomy is sometimes done because the nature of the rare lesion is not suspected. A local enucleation in those cases in which the diagnosis can be established might well be done instead of the more extensive procedure. For tumors situated in the transverse, descending or sigmoid colon, local enucleation or segmental resection with end-to-end anastomosis is to be preferred. Excision of pedunculated lipomas of the rectum in some cases may be accomplished through the proctoscope without a great deal of risk. In the present series of cases, most of which preceded the present-day preparation and chemotherapy, a right colectomy was done in 15 cases, in 6 of which the lipoma was associated with a carcinoma. In 8 cases exteriorization operations were performed; in 5 transcolonic excisions or enucleations; in 3, segmental resections with end-to-end anastomosis; and in 2 combined abdominoperineal resections, both of which were for carcinoma, the lipoma being incidental. In this group there was only 1 death in the immediate postoperative period: the patient, a woman, aged 60 years died from the effects of pneumonia three days postoperatively. Three patients died within four years of the date of operation but all had primary carcinoma associated with the lipoma. Twenty-five patients are still living after operation. In 5 cases no follow-up data were available.

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PERSISTENT TRUNCUS ARTERIOSUS: A CLASSIFICATION ACCORDING TO ANATOMIC TYPES

ROBERT W. COLLETT AND JESSE E. EDWARDS

There has always been considerable confusion concerning the pathologic criteria for the diagnosis of persistent truncus arteriosus. In order to clarify the pathologic diagnosis of persistent truncus arteriosus and to arrive at an applicable classification of this congenital anomaly, an analysis was made of reports of 116 cases of a congenitally defective heart characterized by a single functioning arterial trunk. Ninety-three of these cases were considered to be examples of either persistent truncus arteriosus or partial persistent truncus arteriosus. Of the other 23 cases, 12 were not true examples of this entity even though they had formerly been considered as such by other authors. The remaining 11 cases could not be classified because of inadequate information.

The chief sources of information used were the classic reviews of this type of congenital heart disease made by Taruffi in 1875, Vierordt in 1898, Herxheimer in 1910, Abbott in 1927, Humphreys in 1932 and Lev and Saphir in 1942. However, numerous other reports of cases not included in these reviews were discovered and included in our analysis. Since 1942, at least 11 cases have been reported as examples of the malformation under consideration. However, only 6 of these have been included in the present series as true examples of persistent truncus arteriosus.

From the analysis of the 93 cases of persistent truncus arteriosus, an anatomic classification has been developed on the basis of the embryology of the human heart and great arterial vessels.

Pathologically, a persistent truncus arteriosus consists of a single arterial trunk arising from the ventricular part of the heart. Complete or partial failure of the septum, which normally divides the embryonic truncus arteriosus into the aortic and pulmonary trunk, to form, results in such an anomaly. The single trunk receives blood from both ventricles and supplies the coronary, pulmonary and systemic circulations.

This anomaly may assume numerous variations, and from this fact stems most of the controversy concerning the pathologic diagnosis of persistent truncus arteriosus. In order to clarify the confusion concerning this entity, one must understand the embryologic basis for its development.

EMBRYOLOGIC CONSIDERATIONS

The Truncus Arteriosus and Conus Arteriosus.—Kramer in 1942 published an excellent description of the partitioning of the truncus arteriosus and conus arteriosus and of the formation of the ventricular septum in the embryonic human heart. The truncus arteriosus is the single arterial vessel which passes cephalad as the main outlet from the heart. The conus arteriosus is the conically shaped part of the heart which joins the ventricle with the truncus arteriosus. The line of division between the conus and truncus lies at the level of the formation of the pulmonary and aortic valves. This continuous channel made up of the truncus arteriosus and the conus arteriosus may be called the trun-

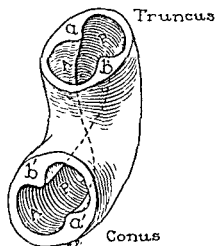


Fig. 460.—The truncocoanal channel showing the two truncoconal ridges (*a*, *a'* and *b*, *b'*) *a*, Truncus ridge in dextrodorsal position, *b*, truncus ridge in sinistroventral position, *a'*, conal ridge in sinistroventral position, *b'*, conal ridge in dextrodorsal position, *A*, aortic channel; and *P*, pulmonary channel.

coconal channel. In the lining of this channel, two opposed and spiraled rows of swellings, the truncoconal ridges, develop (fig. 460). As each ridge is followed caudally, it spirals in a clockwise manner. At the lower level of the conus arteriosus the relations of the opposing ridges are exactly reversed.

As a result of normal growth, these ridges meet in the central axis of the truncocoanal channel and fuse to form a spiral septum that divides the channel into two vessels, the pulmonary trunk and the ascending aorta. The septum which results from the fusion of these spiraled ridges is itself spiraled so that the two vessels which result from this division are also spiraled. Thus, the spiraled nature of the truncoconal ridges is responsible for the spiraling of the pulmonary trunk and aorta about

each other and for the communication of the aorta with the left ventricle and the pulmonary trunk with the right ventricle.²⁰

Below the level of the semilunar valves the conus ridges unite to separate that part of the right ventricle known as the conus pulmonalis from the more modified corresponding portion of the left ventricle that serves as the outlet into the aorta. Complete or partial absence of the truncoconal ridges results in failure of division of the truncoconal channel into the pulmonary trunk and ascending aorta, thus resulting in the congenital anomaly classified as persistent truncus arteriosus.

The Semilunar Valve Cusps.—At the junction of the truncus arteriosus and conus arteriosus, swellings develop on the parietal wall of the truncoconal channel and on the truncoconal septum (fig. 461). From

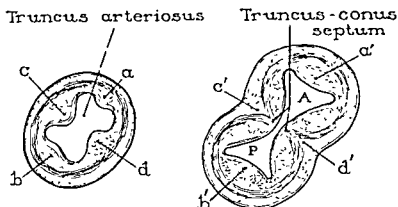


Fig. 461.—Development of the semilunar valve cusps from the parietal wall of the truncoconal channel and on the truncoconal septum. *a*, Intercalated valve swelling which becomes the dorsal cusp of the aortic valve, *a'*; *b*, intercalated valve swelling which becomes the ventral cusp of the pulmonary valve, *b'*; and *c* and *d*, the truncoconal ridge swellings which unite to form the truncoconal septum, *c'* and *d'*, and serve to form the two ventral aortic semilunar valve leaflets and the two dorsal pulmonary valve leaflets (modified from Kramer).

these the usual number of semilunar cusps are formed. However, if the truncoconal ridges fail to form and no other tissue develops into valvular tissue, the only valve leaflets that develop are derived from the parietal wall of the truncoconal channel. Only two semilunar cusps then result. The case of persistent truncus arteriosus reported by Carr, Goodale and Rockwell, in which there were only two semilunar cusps, illustrates such a maldevelopment.

If the truncoconal ridges develop incompletely without the completion of the truncoconal septum, the number of cusps may vary from four to six. In 9 cases of the series reviewed there were four semilunar cusps. In the case reported by Rizzi there were six semilunar cusps.

On the other hand, when there is an eccentric alignment of the truncoconal ridges, three or four valve cusps may result. The size of these

may vary with the degree of eccentricity of the ridges. In the majority of the cases included in the series, there were three cusps, and in 6 of these cases there was partial division of one of the three cusps.

It readily can be seen that the number of valve leaflets present in persistent truncus arteriosus may vary between two and six. In contrast to the statement that four cusps are necessary for the diagnosis of persistent truncus arteriosus,^{57,106} the number of valve cusps present cannot be employed as a significant criterion for the diagnosis of persistent truncus arteriosus.

Pars Membranacea Septi.—The formation of the uppermost portion of the ventricular septum, the membranous portion, is brought about in the region of the conus arteriosus of the ventricles. This is accomplished by the merging of the lower portions of the conus ridges with the right tubercles of the endocardial cushions of the atrioventricular canal and the crest of the muscular ventricular septum. This does not take place, however, through direct fusion of these elements, for, as pointed out by Frazer, Odgers, and Kramer, the embryonic interventricular foramen never completely closes. Rather, the original interventricular foramen above the primary muscular septum is partially remolded into the subaortic conus and the final steps in the partitioning of the ventricle and conus take place where this foramen opens into the right ventricle. The right tubercle of the ventral atrioventricular cushion plays a most important role in this final closure of the interventricular foramen.

As the conus septum, which has developed by the fusing of the conus ridges, grows caudad, it extends toward the right border of the ventricular septum. However, the dextrodorsal conus ridge diverges toward the orifice of the right atrioventricular canal while the sinistroventral conus ridge becomes continuous with the right border of the ventricular septum. The dextrodorsal conus ridge merges with the right tubercle of the atrioventricular canal cushion, thus straddling the right atrioventricular orifice. The fusion of the basal portion of this conus ridge with the right tubercle of the ventral cushion of the atrioventricular canal closes the communication between the right ventricle and the subaortic conus of the left ventricle. With further fusion of (1) the right and left conus ridges, (2) the endocardial cushion tissue at the crest of the ventricular septum and (3) the right tubercle of the ventral atrioventricular canal cushion, the opening between the subaortic conus and the right ventricle is occluded.⁹⁰ This is the final step in the separation of the aortic and pulmonary channels. At least three reports^{20, 42, 74} in the literature concern hearts in which congenital defects occurred in this final closure. They should be considered as examples of partial persistent conus arteriosus.

In accordance with this concept, it is found that ventricular septal

defects of varying magnitude may be associated with persistent truncus arteriosus. The defect may represent complete absence of the entire ventricular septum as in cases of *cor biloculare* or *cor triloculare biatriatum*. This occurred in 19 of the cases of persistent truncus arteriosus in the series reviewed. A complete ventricular septum may be present, with the defect only in the upper part of the conus or truncus septum. Four such cases have been reported in which a complete *pars membranacea septi* was present (Preisz, cases 15 and 16, Kettler, and Graham and Montgomery). There were also cases of a single localized defect in the truncus septum that gave communication between the aorta and pulmonary trunk.

The Pulmonary Arteries.—An understanding of the manner of origin of the pulmonary circulation from the truncus arteriosus involves a consideration of the development of the sixth aortic arches. In vertebrate embryos, six pairs of aortic arches are formed; these connect the ventral aorta with the dorsal aortae. In human embryos the entire series of aortic arches are never present simultaneously. The two most cephalad arches disappear as main channels before the more caudad arches are well established. The fifth arch, if indeed it appears, does so transitorily as a vestigial vessel appended to one of the neighboring arches. Only the ventral and dorsal aortic roots and the third, fourth and sixth arches play an important role in the formation of the permanent vessels. The sixth arches give rise to the right and left pulmonary arteries.

Bremer in 1902 and Llorca in 1933 demonstrated that when the sixth aortic arches are first formed they branch off laterally from the ascending primitive trunk (fig. 462, *a*) to meet the descending dorsal aortic roots. From the caudal aspect of each of the sixth arches buds develop which are the anlagen of the pulmonary arteries. That part of the left sixth arch between the developing left pulmonary artery and its connection with the left dorsal aortic root remains as the ductus arteriosus. Normally, the corresponding portion on the right side disappears.

Llorca, in his study of a series of eight human embryos that varied from 5 to 13 mm. in length, was able to show that the right sixth arch shifts dorsally toward the left sixth arch (fig. 462, *b*). By the time these two arches have become closely aligned, the truncus septum has partially formed, thus separating the aortic and pulmonary circulations as shown in figure 462, *c*. Both Bremer and Llorca emphasized that the right sixth arch shifts so completely to the left, apparently owing to differential growth, that it may appear to spring from the left arch. With the completion of the truncus septum, the circulation appears as it does in figure 462, *d* with a single pulmonary trunk and persistent ductus arteriosus on the left.

It is upon the recognition of these stages in the development of the pulmonary circulation that the anatomic classification of the cases of

persistent truncus arteriosus reviewed by us is based. It was found that the cases could be typed according to the origin of the pulmonary arteries, each type representing different stages in the evolution of the sixth aortic arches as shown in figure 462, *a*, *b*, *c* and *d*.

CRITERIA FOR THE PATHOLOGIC DIAGNOSIS OF PERSISTENT TRUNCUS ARTERIOSUS

Vierordt in 1898 was one of the first to classify cases of persistent truncus arteriosus. He classified 28 cases into three groups according to the following gross anatomic characteristics: (1) partial persistence of the embryonic truncus arteriosus as a single trunk from which the aorta and pulmonary trunks arose, (2) a single arterial trunk with the char-

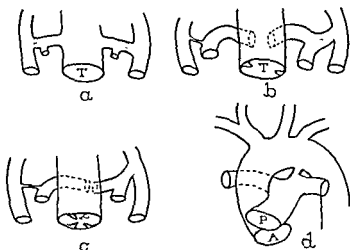


Fig. 462 — *a* to *d*, Development of the sixth aortic arches to form the pulmonary arteries. — Shaded area

acteristics of the aorta and (3) a single arterial trunk with the characteristics of the pulmonary artery. This same classification was accepted by Herxheimer in 1910 and Monckeberg in 1924. The latter author suggested that cases be classified as to "partial" or "complete" persistence of the common arterial trunk on the basis of the degree of septal formation.

Humphreys in 1932 classified the reported cases according to the number of semilunar cusps. She set down eight criteria for the identification of persistent truncus arteriosus. Her first two criteria are acceptable to us and are included in the list of criteria to follow; her last six criteria do not seem valid. She included as criteria the presence of four semilunar valve leaflets, an abnormal topography of the cardiac musculature, an atrial septal defect and abnormal atrioventricular valves.

The number and position of the semilunar valve cusps of the truncus are not significant because, as shown in the discussion on their development, they may vary from only two cusps to as many as six. In 8 cases that met our criteria, there was no atrial septal defect. In the majority of cases the mitral and tricuspid valves were normal.

Lev and Saphir in 1942 stated that the only criterion necessary for diagnosis of persistent truncus was the presence of one large trunk emanating from the heart and giving off the coronary arteries, the pulmonary arteries and the systemic arteries. They referred to their definite cases as "partial," "almost complete" and "complete" types of persistent truncus, in accordance with Mönckeberg's suggestion.

After reviewing numerous descriptions of hearts with a single arterial trunk in which there were no remnants of an atretic second vessel and after investigating the embryologic development of the truncus and conus arteriosus, we have come to the conclusion that only two absolute criteria are necessary for the pathologic diagnosis of persistent truncus arteriosus: (1) there must be only one main arterial trunk leaving the base of the heart and there must be no remnant of an atretic pulmonary artery or aorta and (2) this single arterial trunk must supply branches to the coronary, pulmonary and systemic circulations.

Frequent concomitants of persistent truncus cases but not criteria for pathologic diagnosis are (1) an interventricular septal defect, varying from a small defect of the membranous portion to complete absence of the ventricular septum and (2) an overriding of the interventricular septal defect by the truncus arteriosus, which at times arises more from the right ventricle than from the left. With extreme dextroposition, the truncus may arise solely from the right ventricle.

ANATOMIC CLASSIFICATION OF THE REPORTED CASES OF PERSISTENT TRUNCUS ARTERIOSUS

The most applicable classification of the different types of persistent truncus arteriosus which meet the necessary criteria for a pathologic diagnosis is based on the embryologic stages in the development of the pulmonary arteries from the sixth aortic arches. There are four major types of cases of persistent truncus arteriosus (fig. 463):

Type 1. A single pulmonary trunk and ascending aorta arise from the truncus arteriosus.

Type 2. The right and left pulmonary arteries arise close together from the dorsal wall of the truncus arteriosus.

Type 3. One or both pulmonary arteries arise independently from either side of the truncus arteriosus.

Type 4. There are no pulmonary arteries and there is apparent congenital absence of the sixth aortic arches. The arterial circulation to the lungs is by way of bronchial arteries.

These four major types represent the various stages of arrested development (fig. 462). Type 4 signifies the earliest stage, since no representation of the sixth aortic arches is present. Type 3 represents the next earliest stage in which the sixth aortic arches branch laterally from the truncus (fig. 462, *a*) Type 2 represents a later stage in which the right pulmonary artery has shifted dorsally and to the left to become more closely allied with the left sixth arch (fig. 462, *b* and *c*) Type 1 indicates a much later stage in which the two pulmonary arteries branch from a common pulmonary trunk that in turn takes its origin from the truncus arteriosus. The various types are subdivided on the basis of the direction

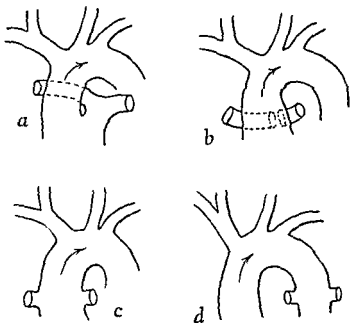


Fig. 463 —The four major anatomic types of persistent truncus arteriosus *a*, Type 1, *b*, type 2, *c*, type 3, and *d*, type 4. Arrow indicates the direction of flow of blood from the heart.

and condition of the aortic arch and the presence or absence of the ductus arteriosus. These types and subtypes are illustrated in figures 464 to 469, which were drawn by Mr. Russell Drake.

Type 1.—Type 1 is represented by 38 cases which are subdivided according to seven different anatomic variations (fig. 464). In each case a short pulmonary trunk and ascending aorta arise from the truncus arteriosus. The first subdivision includes 21 cases, in which the aortic arch turns to the left, the ductus arteriosus is absent and the pulmonary trunk springs from the left side of the truncus (fig. 464, *a*). This subtype represents the largest single group of cases of the series. The second subtype differs from the first in that the pulmonary trunk arises from the

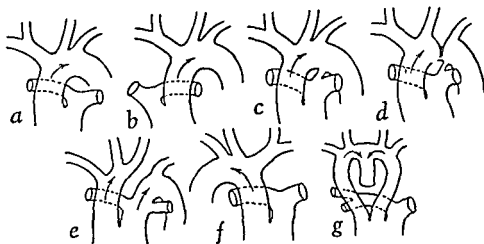


Fig. 464.—Type 1 persistent truncus arteriosus.

Type 1. Single pulmonary trunk and ascending aorta arise from truncus arteriosus (38 cases)

A. Left aortic arch

1. Ductus arteriosus absent

a. *[Faint, mostly illegible text]*

Taussig (1947)

b. Pulmonary trunk from right side (subtype 2, 5 cases) (fig. 464, b). Case reports: Preisz, case 15 (1890); Valdes Diaz and Perez de Los Reyes (1936); Szypulski (1937)†; Walls (1941)*†; Michelson (1943)

2. Ductus arteriosus present

a. Coarctation of aortic arch not present (subtype 3, 3 cases) (fig. 464, c). Case reports: Feller, case 4 (1931); Humphreys (1932); Van Brown (1942)

b. Coarctation of aortic arch present (subtype 4, 1 case) (fig. 464, d). Case report: Feller, case 2 (1931)

c. Complete atresia of part of aortic arch (subtype 5, 1 case) (fig. 464, e). Case report: Preisz, case 16 (1890)

B *[Faint, mostly illegible text]* fig 464, f). Case reports: Rokitansky (1905)*; Feller, case 1 (1931); Roos

C. Double aortic arch (subtype 7, 1 case) (fig. 464, g). Case report: Kerwin (1936)

* Single ventricle.

† Direction of arch assumed to be normal.

‡ Stenosis of pulmonary trunk.

§ Origin of pulmonary trunk high.

right side of the truncus (fig. 464, b). There are 5 cases of this subtype. The third subtype, represented by 3 cases, differs from the first only in that the ductus arteriosus is present and patent (fig. 464, c).

There is only 1 case each of the fourth and fifth subtypes, but they are

Since persistent truncus arteriosus, by definition, is manifested by incomplete division of the truncocoanal channel by the truncocoanal septum, these cases represent partial persistence of the truncus. Therefore, such cases are described in the classification as type 5.

Type 5.—This type is characterized by partial persistent truncus arteriosus, localized defect in the truncocoanal septum and a communication between the aorta and the pulmonary trunk (congenital) (fig. 468).



Fig. 469.—So-called persistent truncus arteriosus

Anomalies considered not to be persistent truncus arteriosus which have been considered as such by other authors (12 cases)

A Single arterial trunk

1

Hunter (1911), Webb (1916)

2 Right aortic arch. Pulmonary supply by way of right ductus arteriosus (?) (1 case) (fig. 469, b) Case report Harris (1926)

B Single arterial trunk

1 Left aortic arch

a Pulmonary supply by way of remnant of ductus arteriosus through innominate artery (right) (2 cases) (fig. 469, c) Case reports Hervé (1910)*, Mehta and Hewlett (1915)

b By way of left innominate artery (1 case) (fig. 469, d) Case report Wood and Williams (1928)

Unclassified group (11 cases)

(Insufficient information—neither direction of aortic arch nor means of circulation to lungs known)

Case reports Cripp (1846), Hervieux (1861), Nunneley (1871); Richardiére

* Direction of arch assumed to be normal

† Single ventricle

Thirteen cases of this type are reported in the literature. They can be subdivided according to the relative size of the truncocoanal septal defect. Small localized defects in the truncus septum were found in 11 cases comprising the first subtype (fig. 468, a). The defects varied in location from a site just above the anterior aortic sinus to a site at the beginning of the arch of the aorta. Those communications in or near the arch of the aorta should not be confused with the so-called window type of persistent ductus arteriosus such as in the case reported by Lutembacher. It is

emphasized that it may be difficult to rule out acquired communications in some of these cases.

In a case reported by Rickards the defect lay behind the anterior semilunar cusp of a bicuspid aortic valve. Below this communication between the pulmonary trunk and the aorta, there was a defect in the membranous portion of the ventricular septum.

In 2 cases, one reported by Charteris and another by Jacobi and Heinrich, there was a communication between the aorta and the conus of the right ventricle representing a defect in the final step in the separation of the aortic and pulmonary channels as described in the discussion of the embryology of the pars membranacea. These could be classed as cases representing partial persistence of the conus arteriosus due to lack of completion of the conus septum in localized areas.

Livingston reported a case in which there was a defect between the aorta and right ventricle at the level of the tricuspid valve; this defect represented the lack of fusion of the basal portion of the dextrodorsal conus ridge with the right tubercle of the ventral cushion of the atrio-ventricular canal.

Localized weakness in the completed truncoconal septum may result in an aneurysm of that particular portion of the septum. Ten cases of such aneurysms^{1, 8, 43, 51, 69, 71, 107, 112, 114, 124} have been reported. It is questionable if these can all be considered to be congenital defects because only 1 of the patients died at an age of less than 26 years. This was the case reported by White in a boy aged 15 years.

In the remaining 2 cases of type 5 there was a large defect in the truncus septum (fig. 468, *b*). The right and left pulmonary arteries arose from the posterior left aspect of the partial persisting truncus. Except for the presence of the intact aortic and pulmonary semilunar valves, these cases resemble those of type 2.

In 6 of the cases of type 5, the ductus arteriosus had formed but was closed at the time of necropsy. The ductus arteriosus was absent in 2 cases, 1 of which was reported by Moorhead and Smith in 1923 and the other by Bain and Parkinson in 1943. In Hektoen's case, the ductus arteriosus was persistent and patent.

CASES CONSIDERED NOT TO BE PERSISTENT TRUNCUS ARTERIOSUS WHICH HAVE FORMERLY BEEN CONSIDERED AS SUCH

The remaining 12 cases of the 116 in this series are considered not to be cases of persistent truncus arteriosus (fig. 469). The essential features of these cases include the presence of a single arterial trunk that follows the course of the aorta and a pulmonary arterial supply that is acquired by means of a persistent ductus arteriosus. There are 8 cases in which the source of blood to the lungs is by a normally located ductus,

that is, the right and left pulmonary arteries appear to branch from the ductus arteriosus (fig. 469, *a*). Such cases have been included as typical examples in former series of cases of persistent truncus arteriosus. However, since the right and left pulmonary arteries are derived as branches of the proximal portions of the right and left sixth aortic arches, the presence of both of them presupposes that the proximal portion of the right and left sixth aortic arches were present at one time. Since the right and left pulmonary arteries showed no connection with the truncus or a derivative of it, those parts of the sixth arches must have been present at one time but must have subsequently disappeared. Under these circumstances it is impossible to state whether they had arisen from a truncus arteriosus or from a pulmonary trunk which had developed from partitioning of the truncus. There are numerous cases in the literature which resemble these 8 cases in that the pulmonary supply was obtained through a ductus arteriosus, but in which an atretic pulmonary trunk is present and connected with the functioning ductus. Inasmuch as it is impossible to determine in these 8 cases whether or not the truncus had in fact been partitioned at one time, it is impossible to include them unequivocally as examples of persistent truncus arteriosus.

In the case of a right aortic arch reported by Harris in 1926 there was complete absence of the left lung. The arterial supply to the right lung appeared to be by way of a right-sided ductus arteriosus (fig. 469, *b*). Thus interpreted, a right-sided pulmonary trunk might have developed at one time but subsequently disappeared. The stillborn infant which Harris described was markedly deformed. It was a case of phocomelus with congenital cystic elephantiasis.

In the last 3 cases a single arterial trunk arose from the base of the heart but the pulmonary arterial supply was by means of an anomalous ductus arteriosus that branched from the innominate artery. The anomaly described in the cases reported by Herdheimer, and Mehta and Hewlett is illustrated in figure 469, *c*. The anomaly described by Wood and Williams is illustrated in figure 469, *d*.

ANOMALIES ASSOCIATED WITH PERSISTENT TRUNCUS ARTERIOSUS

Associated with persistent truncus arteriosus in the 93 cases of the five types given in the classification were numerous other cardiac and vascular anomalies (table 1). The origin of the truncus arteriosus in the first four types and the variation in the number of semilunar valve cusps are shown in table 2. The direction of the aortic arch and the variation in number and position of the coronary arteries are shown in table 3.

Various noncardiac congenital anomalies that were coexistent with persistent truncus are listed in table 4.

The age of the patients at the time of death in the cases reviewed are

TABLE 1
CARDIAC AND VASCULAR ANOMALIES ASSOCIATED WITH PERSISTENT TRUNCUS
ARTERIOSUS (93 CASES)

Anomaly	Cases
Atrial septal defect	8
Common atrioventricular valve	19
Single ventricle	19
Bilocular heart	4
Trilocular heart	5
Stenosis of truncus	1
Stenosis of pulmonary trunk	2
Ectopic coronary arteries	6
One present	7
Three present	1
One from pulmonary artery	1
Right aortic arch	11
Double aortic arch	1
Absent ductus arteriosus	71
Functioning ductus arteriosus	12
Coarctation of aortic arch	1
Complete interruption of aortic arch	2
Two superior venae cavae	2
Abnormal number of pulmonary veins	20
Two pulmonary veins	9
One pulmonary vein	7
Three pulmonary veins	4
Abnormal brachiocephalic vessels	11
Four brachiocephalic vessels	6

TABLE 2
ORIGIN OF THE TRUNCUS ARTERIOSUS AND THE NUMBER OF SEMILUNAR VALVES
ACCORDING TO THE VARIOUS TYPES

	Type				Total
	1	2	3	4	
Origin of truncus					
Both ventricles (overriding septal defect)	17	11	3	7	38
Right ventricle	7	3	4	2	16
Left ventricle	2	0	0	0	2
Single ventricle	8	9	2	0	19
Unknown	4	0	0	1	5
Number of semilunar cusps					
Two	0	1	0	0	1
Three	14	15	7	7	43
Three plus*	1	4	1	0	6
Four	9	0	0	0	9
Six	1	0	0	0	1
Not given	13	3	1	3	20

* Evidence of partial division of one of the three cusps.

shown in table 5. It is interesting to note that of the four major types, only in the cases of type 2, in which the right and left pulmonary

TABLE 3

THE DIRECTION OF THE AORTIC ARCH AND THE VARIATION IN NUMBER AND POSITION OF THE CORONARY ARTERIES ACCORDING TO THE TYPES OF PERSISTENT TRUNCUS ARTERIOSUS

	Type					Total
	1	2	3	4	5	
Direction of aortic arch						
To the left	20	18	6	7	13	64
To the right	6	2	2	1	0	11
Double arch	1	0	0	0	0	1
Not known	11	3	1	2	0	17
Totals	38	23	9	10	13	93
Number of coronary arteries						
Number given	19	17	7	7	4	54
Three	1	0	0	0	0	1
Two	16	14	6	6	4	46
One	2	3	1	1	0	7
Number not given	19	6	2	3	9	39
Ectopic coronary arteries	2	3	1	0	0	6

TABLE 4

NONCARDIAC CONGENITAL ANOMALIES AND INFLAMMATORY CONDITIONS ASSOCIATED WITH PERSISTENT TRUNCUS ARTERIOSUS

Anomaly or Inflammatory Condition	Cases
<i>Situs inversus</i>	3
Symphys apus	1
Aplasia of spleen	2
Aplasia of anus	1
Aplasia of kidneys and ureters	1
Aplasia of testes	1
Horseshoe kidney	2
Polycystic kidney	1
Spina bifida	2
Cleft palate	1
Omphalocele and ectopia cordis	1
Absent diaphragm	1
Polydactylism	1
Microphthalmus	1
Bone defects (arm, digits)	3
Subacute bacterial endocarditis	1
"Fetal endocarditis"	4
Fibrous endocarditis	1
Cerebral abscess	3

arteries arose close together from the dorsal wall of the truncus, and in cases of type 4, in which no pulmonary arteries were present, did any persons reach maturity. In the cases of type 2, 3 persons died between the

ages of 16 and 36 years. Five with type 4 lesions died between the ages of 18 and 36 years. It is also interesting that few deaths occurred between the ages of 5 and 16 years; only 3 patients with lesions of the first four major types died in this period, at ages 5,⁴³ 5½⁵⁰ and 13½⁵¹ years respectively. Twenty-six of the 85 patients for whom the age of death was given died during the first week of life (30.6 per cent). Thirty persons died in the age period of 8 days to 6 months inclusive and 8 from the ages of 7 to 14 months inclusive. Nearly a third of the patients lived to be more than 6 months of age. About 10 per cent of the patients lived to the age of 20 years or more.

The inflammatory conditions stated as being commonly associated with congenital heart disease were conspicuous by their paucity. In only 1 of the 80 cases of the four major types was the patient reported to have had subacute bacterial endocarditis. In 4 cases there were warty vegeta-

TABLE 5

AGE OF PATIENTS WITH PERSISTENT TRUNCUS ARTERIOSUS AT THE TIME OF DEATH

AGE AT DEATH	TOTAL	CASES BY TYPE				
		1	2	3	4	5
Stillborn-7 days	26	11	10	3	1	1
8 days-6 mo	30	17	7	2	3	1
7-14 mo	8	3	1	3	0	1
15 mo-9 yr	6	2	0	0	1	3
10-19 yr	5	1	2	0	2	0
20 yr or more	10	0	2	0	3	5
Age not given	8	4	1	1	0	2
Totals	93	38	23	9	10	13
Range of ages		(1 hr-13 yr.)	(Stillborn-36 yr.)	(1 hr-14 mo)	(1 hr-33 yr)	(Newborn-49 yr)

tions on the atrioventricular valves. These were considered by the respective authors to be evidence of fetal endocarditis. Fibrous endocarditis was described in 1 case (Santa Cruz). Three patients reported on by Greenspon and Leaman, Hulse and Caesar, respectively, died of cerebral abscesses as a complication of the congenital heart disease.

SUMMARY

A review is made of the embryology of the human heart, with emphasis on the development of the septal system which divides the ventricles, the conus arteriosus and the truncus arteriosus to form two separate circulations. This review is based fundamentally upon work done by Kramer and Patten. It is pointed out that by defective growth of the truncoconal ridges which normally unite to form the truncoconal septum, the original truncoconal channel remains as a persistent truncus arteriosus.

On the basis of this review, the two absolute criteria set up for the pathologic diagnosis of persistent truncus arteriosus are (1) that there must be only one main arterial trunk leaving the base of the heart and there must be no remnant of an atretic pulmonary trunk or aorta and (2) that this single arterial trunk must supply branches to the coronary, pulmonary and systemic circulations. The contribution of the sixth aortic arches in the formation of the pulmonary arteries is pointed out. On the basis of the embryologic development of the pulmonary arteries from the sixth aortic arches, an anatomic classification of the cases of persistent truncus arteriosus into four major types and one minor type is made, grouping the cases by types according to various stages of arrested development in this embryologic process.

In this classification, type 4 (10 cases) signifies the earliest stage, since no representation of the sixth aortic arches is present. Type 3 (9 cases) represents the next earliest stage, in which the sixth aortic arches branch laterally from the truncus. Type 2 (23 cases) represents a later stage in which the right pulmonary artery has shifted dorsally and to the left to become more closely allied with the left sixth arch. Type 1 (38 cases) indicates a much later stage in which the two pulmonary arteries branch from a common pulmonary trunk that in turn takes its origin from the truncus arteriosus. These various types are subdivided on the basis of the direction and condition of the aortic arch and the presence or absence of the ductus arteriosus.

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THE SURGICAL CLINICS OF NORTH AMERICA

NATIONWIDE NUMBER

SYMPOSIUM ON RECENT ADVANCES IN SURGERY

FOREWORD

The medical profession strives to disseminate current information as rapidly as possible. In this volume, particular emphasis has been placed on presentation of knowledge recently gained; however, in order to maintain completeness, the authors have included important current ideas, even though they may have been discovered or developed several years previously. By no means are all of the papers devoted to operative technic, although in a large proportion of instances, current operative methods are discussed in principle and occasionally in detail. More often the authors have endeavored to summarize the important modern thoughts in their respective subjects, and likewise present recent data on results.

Physiologic principles in diagnosis as well as treatment have been rightly emphasized herein. Although perfection in technic is an achievement to be sought by all, there is great danger that a surgeon steeped in the principles of technic may neglect the important physiologic knowledge which, when utilized in preoperative and postoperative care, plays such an important role in the final outcome.

In general, the subjects of the contributions presented in this volume have been chosen as those considered the most important in the surgical problems of today. Rare conditions are not discussed. It is, therefore, hoped that the information contained herein will be found very useful and practical.

WARREN H. COLE, M.D.

NEWER ANTIBACTERIAL AGENTS IN SURGERY

W. A. ALTEMEIER, M.D., F.A.C.S.*

The rapid growth of chemotherapy during the past seven years^{1,2} has made it difficult for the clinical surgeon to keep informed regarding the many new antibacterial agents, recent modifications of the older ones, and the changing concepts of their dosage schedules, mode of action, and methods of administration. More than 175 antimicrobial agents have been described in the literature up to April 1, 1949, and many hundreds more have been under laboratory investigation. Only a few of these have retained their antimicrobial activity in vivo or have been sufficiently low in toxicity³ to permit their clinical use for the control of surgical infections. This discussion is intended to review our knowledge of the most promising chemotherapeutic agents which have been introduced recently so that these substances may be used safely and effectively. Although the efficiency of penicillin and streptomycin has been greatly increased by recent preparations and modifications of dosage schedules, their consideration is not within the scope of this article.

Bacitracin, polymixin or aerosporin, aureomycin and chloromycetin are the most promising of the newer antibacterial agents. Each has withstood the preliminary and intensive laboratory investigation and each is now being thoroughly investigated clinically.

BACITRACIN

General Considerations.—Bacitracin is an antibiotic agent originally described by Johnson, Anker and Meleney¹⁰ in 1945. It is derived from the Tracey strain of *Bacillus subtilis* which was recovered in May 1943 from a culture of débrided tissue removed from the compound fracture of a patient whose name was Tracey. Its distribution for parenteral use is still on allocation for experimental investigation, but the Federal Drug Administration has authorized its general distribution for topical or local applications.

Bacitracin's *antibacterial spectrum* (Table 1) is extensive and very similar to that of penicillin.¹¹ Bacitracin has been found to be effective in vitro against most pathogenic strains of hemolytic streptococci, nonhemolytic streptococci, coagulase-positive staphylococci, pneumococci, gonococci, diphtheriae bacillus, anaerobic cocci in general, the various clostridia of gas gangrene, *Treponema pallidum*, the spirochetes

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of the mouth, the actinomyces, and the *Endamoeba histolytica*. It has in that its bactericidal activity appears to be directly proportional to its concentration.

The chief attributes of bacitracin as a chemotherapeutic agent are as follows:

1. Bacteria subjected to its action show only moderate tendency to develop resistance to the compound, either in vitro or in vivo.
2. Blood, pus, wound exudates, or necrotic tissue do not inhibit or destroy its action.
3. It is not inhibited by bacteria which produce penicillinase. Meloney believes it to be of considerable value in the treatment of mixed infections, partially those secondarily contaminated by gram-negative, peni-

TABLE 1
MICROORGANISMS SENSITIVE TO BACITRACIN

Hemolytic streptococcus	<i>Bacillus pseudodiphtheriae</i>
Nonhemolytic streptococcus	<i>Clostridium tetani</i>
Microaerophilic streptococcus	<i>Clostridium welchii</i>
Anaerobic streptococcus	<i>Clostridium histolyticus</i>
<i>Staphylococcus aureus</i>	<i>Clostridium septicum</i>
<i>Staphylococcus albus</i>	<i>Clostridium oedematiens</i>
Anaerobic <i>staphylococcus</i>	<i>Clostridium sporogenes</i>
<i>Pneumococcus</i>	<i>Clostridium sordelli</i>
<i>Meningococcus</i>	<i>Actinomyces bovis</i>
<i>Gonococcus</i>	<i>Treponema pallidum</i>
<i>Bacillus diphtheriae</i>	<i>Endamoeba histolytica</i>

illinase-producing bacteria which may inhibit the action of penicillin on the gram-positive etiologic components.

4. It can be given at more prolonged intervals since it is eliminated from the body slowly.

5. Its effectiveness against microbes is in direct proportion to its concentration.

6. It has shown less tendency to produce allergic or hypersensitive reactions in patients treated either systemically or locally than has either penicillin or streptomycin.

7. It is effective against many penicillin- and streptomycin-resistant infections. This is one of its chief indications for clinical use at the present time. A synergistic effect may occur when bacitracin is used with penicillin, particularly in the treatment of syphilis and resistant staphylococcal infections.

8. It is superior to penicillin in the treatment of many anaerobic or microaerophilic streptococcal infections, particularly chronic progressive synergistic gangrene and undermining burrowing ulcer.

9. Bacitracin is of considerable value in the treatment of ulcerations and granulomas of the colon produced by the *Endamoeba histolytica*.

The following *disadvantages* of bacitracin as a chemotherapeutic agent when compared with penicillin may be listed:

1. As yet it has not been produced in pure crystalline form.

2. At the present stage of its impurity, it produces evidence of renal irritation in some instances after its parenteral injection in man. This nephrotoxic effect has tended to limit the dosage, the scope of action and the duration of treatment of bacitracin.

3. It has been learned that the toxicity of bacitracin varies with different batches, and possibly with different methods of its production. For experimental use during the past nine months, only those preparations of bacitracin have been used which have an LD₅₀ when 500 units are injected intravenously in 20-gm. mice.

4. Local pain and induration may occur at the site of injection.

Administration and Dosage.—When injected parenterally in humans, bacitracin is readily absorbed and diffused throughout the tissues in a manner similar to penicillin. After oral administration, bacitracin is only slightly absorbed and this route of administration cannot be used for systemic purposes.

The initial parenteral dose recommended at the present time is 10,000 units intramuscularly every six hours for forty-eight to seventy-two hours (Fig. 470). If no signs of nephrotoxicity develop within this period, the dose may be increased to 15,000, 20,000 or 30,000 units every six hours.

Doses in excess of 30,000 units are not recommended unless the infecting organism is relatively resistant to bacitracin and no signs of nephrotoxicity develop with lesser preliminary dosage. Bacitracin should not be given more often than once every six hours. It should be administered intramuscularly in a solution of 2 per cent novocain in physiological saline to minimize pain at the site and time of injection.

Bacitracin may be used topically in the form of a dilute solution in physiological saline or an ointment containing 50 to 500 units per cubic centimeter or gram. In my own experience a cathowax base has been most satisfactory for bacitracin ointment, and a preparation of this type is produced commercially.

Untoward Effects.—When applied topically to the skin, soft skeletal tissues, or the central nervous system, no evidence of toxicity has been noted. Pain lasting from fifteen to forty-five minutes immediately follow an injection of some lots of bacitracin. With other lots little or no pain will follow an injection of bacitracin. A delayed reaction characterized by pain, redness, local heat, and induration may occur occasionally within twelve to twenty-four hours after injection. On one occasion, a herpetiform rash developed about the site of each injection in one of the author's cases. General reactions such as those with nausea and anorexia have been observed.

Signs of nephrotoxicity may occur on the third or fourth day of treatment.

denced by urinary albuminuria, granular casts, renal epithelial cells and microscopic hematuria. In some of the cases manifesting albuminuria and other signs of renal irritation, elevation of the blood urea nitrogen or nonprotein nitrogen levels may occur. The degree of albuminuria may vary from a trace to 4 plus (Fig. 471) and may also vary with different lots of bacitracin. The albuminuria may be transient, disappearing while the patient is under therapy, or it may persist or increase during continued bacitracin treatment. Pulaski reported an incidence of nephrotoxic phenomena in about half of a series of twenty patients treated with

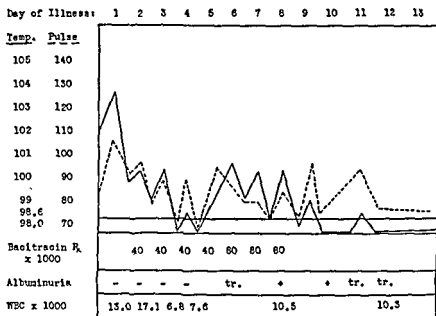


Fig. 470 — A F, a 40 year old Negro, was admitted to the Cincinnati General Hospital on October 19, 1948 with acute postoperative cellulitis of the face and neck.

hours, 1 plus albuminuria developed

bacitracin. Subsequent information indicated that he was using particularly toxic lots, however. Discontinuation of bacitracin is usually followed by disappearance of the albuminuria within three to seven days. The lesion produced in the kidney has been shown to be a lower nephron nephrosis. In animals, repair of the damaged kidney tubules occurred spontaneously after cessation of therapy.

Attempts are being made by chemists either to separate the toxic factors from the therapeutically active factor of bacitracin or to nullify in some manner bacitracin's toxic effects. Although some evidence has been introduced to indicate that the nephrotoxicity is inherent in the

bacitracin molecule, other indications suggest a definite possibility and even a probability that a nontoxic form of bacitracin may be produced which could be given safely in much larger doses. A recent analysis of several different lots of bacitracin has revealed several polypeptides which differ somewhat in the relative proportion of the amino acids which they contain. Other studies indicate that bacitracin is a polypeptide of considerable molecular size with a molecular weight between 2000 and 5000.

Laboratory Control.—Before the start of bacitracin therapy, a urinalysis, phenolsulfonphthalein renal function test, and determinations of the

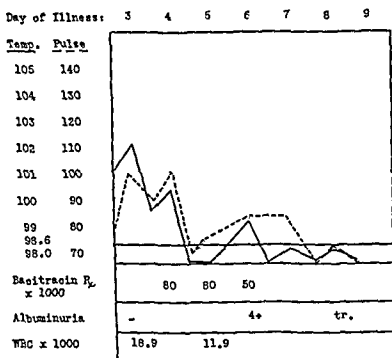


Fig. 471.—G. B., a 39 year old Negro, was admitted to the Cincinnati General Hospital on December 14, 1948 with acute cellulitis of scalp and face complicating a laceration. Chart illustrates the development of albuminuria 4+ on the third day of parenteral bacitracin therapy. Albuminuria promptly receded spontaneously after discontinuation of bacitracin. Good response of infection to the antibacterial agent.

blood urea nitrogen or nonprotein nitrogen should be made. Should definite evidence of renal damage exist in a given patient, bacitracin therapy should either not be used or be used with great caution when no other available chemotherapeutic agent is effective against the particular infecting agent of that patient. If no evidence of renal damage is evident, parenteral bacitracin may be started. During the first four days of therapy, daily urinalyses should be done and phenolsulfonphthalein renal function tests and determinations of the blood urea nitrogen should be performed every other day. If albuminuria or granular casts develop, further administration of bacitracin may be continued with

caution. However, if the albuminuria increases to 3 or 4 plus or if hematuria develops, it is wisest to discontinue further administration of the agent, particularly if nausea, vomiting or signs of nitrogen retention occur. If there are no signs of renal damage, the dose of bacitracin may be increased if necessary and urinalyses and blood urea nitrogen determinations may be done every third or fourth day.

Clinical Indications.—At the present time clinical studies are being carried out in human patients at New York, Philadelphia, New Orleans and Cincinnati to determine the indications and limitations of this new antibiotic agent in the treatment of surgical infections. In general, the clinical indications are essentially the same as those for penicillin. On the other hand, bacitracin is of particular value in the treatment of sulfonamide-, penicillin- and streptomycin-resistant infections. In some instances, it has exerted a synergistic effect with penicillin in the treatment of resistant staphylococcal infections and syphilis. In the treatment of chronic progressive cutaneous gangrene, bacitracin has been superior to penicillin, causing arrest of the process and permitting spontaneous resolution beginning within forty-eight to seventy-two hours. Infections produced by the hemolytic staphylococcus, the hemolytic streptococcus, pneumococci, gonococci, meningococci and anaerobic cocci are usually susceptible to its action.

In my own studies¹² and in those of Sandusky,¹³ bacitracin has been found to be very effective in the arrest and control of experimental gas gangrene produced in guinea pigs. When administered orally in doses from 10,000 to 40,000 units every six hours, intestinal infections produced by the *Endamoeba histolytica* have been successfully treated, the organisms disappearing from the stool in approximately forty-eight to seventy-two hours.

Further refinement with a reduction of the nephrotoxic factors of bacitracin are necessary before the drug will be acceptable for general clinical use and before it can be distributed widely for this purpose.

POLYMYXIN (AEROSPORIN)

General Considerations.—Polymyxin is a polypeptide of variable amino acid content derived from cultures of the *Bacillus aerosporus* which is also known as the *Bacillus polymyxa*. Four types have been identified, A, B, C and D. Polymyxin B is the type available for clinical experimentation. When originally described by Ainsworth, Brown and Brownlee,¹⁴ it was designated as Aerosporin or Bacillosporin. Stansley and others¹⁵ reported the extraction of polymyxin from cultures of *Bacillus polymyxa*. Later it was determined that the *Bacillus aerosporus* and the *Bacillus polymyxa* are one and the same organism, and it has been agreed among the principal investigators concerned that the various antibiotic agents derived from this bacterium henceforth will be designated as polymyxin A, polymyxin B, etc. The most promising one, polymyxin B, has a highly selective antibacterial activity for gram-negative

bacteria, its antibacterial efficiency for such organisms being similar to that of streptomycin (Table 2).

One distinct advantage of polymixin B is the lack of resistance developed by strains of bacteria subjected to its action; a factor which is in definite contrast with streptomycin. Polymixin B is readily produced, relatively stable, and has a selective action of high intrinsic potency.¹⁶ Weight for weight, it is said to have essentially the same order of chemotherapeutic activity against gram-negative bacteria as penicillin has against the gram-positive. It is unique as a chemotherapeutic agent in its remarkable specificity for gram-negative bacteria only, which distinguishes it from all other antibiotics thus far reported. Polymixin is bactericidal in action, not bacteriostatic. Time of exposure, the number of bacteria, and the concentration of polymixin affect its antibacterial property. Some evidence has been presented that polymixin may not be detectable in effective concentrations in the bile, urine, or cerebrospinal fluid after its parenteral injection, although this has not been proved.

TABLE 2
BACTERIA SENSITIVE TO POLYMXIN B

<i>H. influenzae</i>	<i>A. aerogenes</i>
<i>H. pertussis</i>	<i>Pseudomonas pyocyaneus</i> (some strains)
<i>B. typhosus</i>	<i>Vibrio coli</i>
<i>B. paratyphosus</i>	<i>B. dysenteriae</i>
<i>E. coli</i>	<i>B. tularensis</i>
<i>N. catarrhalis</i>	<i>B. pestis</i>

Administration and Dosage.—Parenteral administration is necessary for the production of adequate antibacterial levels in the circulating blood and tissues. When injected intramuscularly, it is readily absorbed and adequate levels are produced in the circulating blood for relatively short periods of time, maintenance doses being necessary every four hours. The parenteral dosage recommended is usually 8 mg. per kilogram of body weight every four hours. When given orally, polymixin is not absorbed in significant amounts from the alimentary tract, but it is effective in greatly decreasing the number of intestinal bacteria of the gram-negative variety. It has been used effectively when applied topically in an ointment base of carbowax or in saline solution to areas infected by susceptible bacteria.

Untoward Effects.—Tenderness and pain occurring at the site of injection have been slight or of moderate degree. In about one-third of my cases treated with full therapeutic dosage, some evidence of toxicity such as vertigo, headache, albuminuria and hematuria occurred. When used topically, no evidence of toxicity has been noted.

Laboratory Control.—Urinalysis should be done preceding the onset of polymixin therapy and daily for the first three days. Thereafter, urinalysis may be done every third or fourth day. Phenolsulfonphthalein

and blood urea nitrogen determinations should be done when indicated. Usually we have also made complete blood counts at least every third day while the patient was under polymixin therapy, although we have not discovered any evidence of toxicity by this means.

Clinical Indications.—Polymixin may be used alone in the treatment of infections produced by gram-negative bacilli such as *E. coli*, *A. aerogenes*, *E. typhosus* and *N. catarrhalis*. In the therapy of established surgical infections produced by gram-negative bacteria, we have found it in general to be somewhat less effective than streptomycin, although our experience has been limited. In the management of gram-negative bacterial bacteremias and mixed infections of wounds, satisfactory responses were obtained. It may also be used in combination with penicillin or other agents in the treatment of mixed bacterial infections of wounds. The general clinical use of polymixin will not become widespread in all probability unless means of decreasing its toxicity and of increasing its antibacterial effect are developed.

TABLE 3
MICROORGANISMS SENSITIVE TO AUREOMYCIN

Meningococcus	<i>H. influenzae</i>
Gonococcus	<i>B. typhosus</i>
Pneumococcus	<i>B. paratyphosus</i>
Staphylococcus aureus	<i>B. tularensis</i>
Staphylococcus albus	<i>N. catarrhalis</i>
Streptococcus faecalis	<i>B. dysenteriae</i>
Streptococcus mitis	<i>B. faecalis alcaligenes</i>
<i>E. coli</i>	<i>Borrelia novyi</i>
<i>A. aerogenes</i>	<i>Treponema pallidum</i>
<i>Br. melitensis</i>	<i>Rickettsia rickettsii</i>
Undetermined number of viruses	

AUREOMYCIN

General Considerations.—Aureomycin is a particularly promising new chemotherapeutic agent. An antibiotic agent^{17, 18} recently derived from a strain of *Streptomyces aureofaciens*, aureomycin is a moderately stable powder which remains effective in water solution in acid pH, but which deteriorates rapidly in alkaline solution. It is effective against actively growing bacteria and ineffective for adult or resting bacterial cultures. The antibacterial activity of aureomycin is relatively unaffected by anaerobic conditions and greater in acid medium. Bacterial resistance to it does not develop easily in vitro. It has an antibacterial activity against a large number of bacteria in vitro, being equal to that of streptomycin against most gram-negative bacilli and less than that of penicillin, but more than that of streptomycin against most gram-positive organisms.

Proteus vulgaris and *Pseudomonas aeruginosa* are relatively resistant to its action. It manifests equal antimicrobial activity against penicillin-

sensitive and penicillin-resistant gram-positive pyogenic cocci as well as against streptomycin-sensitive and streptomycin-resistant microorganisms. It is also active against streptomycin-dependent bacteria. There is increasing evidence of its antirickettsial and antiviral activity. One very significant characteristic is its ability to attack microbes such as viruses which are located inside the cell membrane of human cells.

Methods of Administration and Dosage.—When administered orally, aureomycin is readily absorbed from the gastroenteric tract into the general circulation, and effective antibacterial levels are readily produced in the blood and tissues.^{19, 20} After the oral administration of a single dose of 0.75 to 1 gm., a therapeutic blood level usually is rapidly produced and maintained at a rather constant level for twelve or more hours. Detectable concentrations of aureomycin may persist in the blood for twenty-four to thirty hours,²⁰ indicating that this antibiotic substance is excreted more slowly than any of the previously reported agents. In patients receiving repeated doses of 750 mg. every six hours, blood levels of 2 to 8 micrograms per cubic centimeter is maintained.

From the blood stream, aureomycin is diffused readily into the cerebrospinal fluid, pleural fluid, bile and peritoneal fluid. It is readily and constantly excreted by the kidneys, and high concentrations may be developed in the urine in two to sixteen hours after administration. It may also be injected intravenously, there being a 5:1 ratio in dosage between the oral and parenteral methods of administering this agent. The oral dosage employed varies with the infection and the treatment, but in general it has been approximately 50 to 100 mg. per kg. per day. For the average adult, dosages of 500 mg. every four hours or 750 mg. every six hours are usually effective, the duration of treatment varying with the individual infection (Fig. 472).

In general, the oral method of administration is preferred, but intravenous administration may be desirable when a high level is wanted at once or when absorption from the gastrointestinal tract is not possible during the postoperative state or for some other reason. Aureomycin blood levels may be augmented by the oral administration of caronamide.

Untoward Effects.—Pharmacological studies in animals indicate that the toxicity of this drug is extremely low except after intravenous administration when hemoglobinuria and anemia have been observed. No reports of anemia, jaundice, azotemia, drug fever or agranulocytosis have been noted in patients. Nausea and vomiting occasionally occur.

The intravenous administration of aureomycin may be followed by local thrombophlebitis in 30 to 40 per cent of the cases, depending upon the duration of therapy and the dosage. Chills and fever occasionally have been seen. No serious effects, however, have been noted.

Laboratory Control.—No specific laboratory procedures are recommended at the present time for the detection of toxic manifestations to this antibiotic agent.

Clinical Indications.—The full clinical potentialities of aureomycin are still undetermined. It is indicated in the treatment of many gram-posi-

tive and gram-negative surgical infections, as well as in various rickettsial and virus infections. It is of particular value in the management of penicillin-, streptomycin- and sulfonamide-resistant infections. Preliminary experimental and clinical observations in acute septic peritonitis secondary to inflammation or perforation of the gastroenteric tract suggest that aureomycin is a valuable adjunct to the indicated surgery.²¹ It is equal to streptomycin in the treatment of many gram-negative infections, and apparently superior to it in the therapy of urinary tract infections. It is less effective than penicillin but more effective than streptomycin in the management of gram-positive bacterial infections. It has been shown to be of value in the rickettsial and virus infections, including atypical

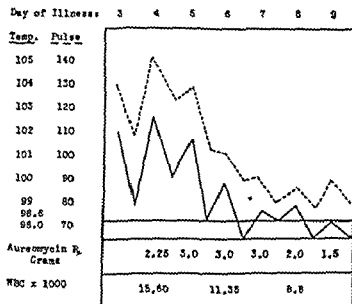


Fig. 472.—D M, a 44 year old white man, developed acute cholangitis four months after cholecystectomy and exploration of common duct. Treatment with aureomycin was followed by prompt improvement with rapid fall of temperature and pulse, disappearance of chills, and marked but incomplete clearing of jaundice.

pneumonia, typhus fever, Rocky mountain spotted fever, and psittacosis. This antimicrobial agent will undoubtedly be a valuable addition to the field of chemotherapy.

CHLOROMYCETIN

General Considerations.—Chloromycetin, or chloramphenicol, is a new and exceedingly promising antibiotic agent which has been derived from cultures of the species *Streptomyces venezuelae*.^{22, 23, 24} Originally it was isolated from a sample soil collected in a mulched field near Caracas, Venezuela. It has a marked antibacterial activity against a large number and variety of micro-organisms in vitro.²⁵ (Table 4)

The antiviral and antirickettsial activity of chloromycetin has been very effective and significant.^{26, 27}

Chloromycetin shows remarkable activity against the gram-negative bacteria including many of those in the colon-typhoid group, being ten to thirty-five times more active than penicillin. It showed less activity against the tubercle bacillus than streptomycin, and much less activity than penicillin against the gram-positive cocci. In our recent experience, however, the antibacterial activity of chloromycetin for gram-positive cocci and gram-positive bacilli has been greater than originally anticipated. It has no significant effect against protozoa and fungi.

Methods of Administration and Dosage.—Chloromycetin may be administered orally or parenterally, but only the oral route is recommended at present. After its oral administration, it is readily absorbed from the intestinal tract and adequate antibacterial levels are produced within

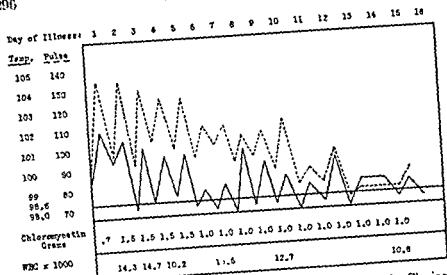
TABLE 4
MICROORGANISMS SENSITIVE TO CHLOROMYCETIN

<i>E. coli</i>	<i>Borrelia recurrentis</i>
<i>A. aerogenes</i>	<i>B. dysenteriae</i>
<i>B. typhosus</i>	<i>Rickettsia prowazeki</i>
<i>B. paratyphosus</i>	<i>Rickettsia rickettsi</i>
<i>Proteus vulgaris</i>	<i>Rickettsia orientalis</i>
<i>H. pertussis</i>	<i>Rickettsia mooseri</i>
<i>Br. suis</i>	<i>Psittacosis virus</i>
<i>Br. melitensis</i>	<i>Lymphogranuloma virus</i>
<i>Salmonella enteritidis</i>	<i>Atypical pneumonia virus</i>
<i>B. tularensis</i>	<i>Staphylococcus aureus</i>
<i>N. catarrhalis</i>	<i>Staphylococcus albus</i>
<i>Pseudomonas aeruginosa</i> (some strains)	<i>Streptococcus hemolyticus</i>
	<i>Streptococcus viridans</i>
	<i>B. anthracis</i>
	<i>Pneumococcus</i>

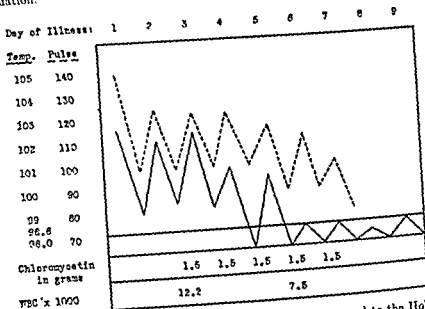
thirty minutes in the circulating blood. Therapeutically active levels persist in the circulating blood for four to eight hours or more after a single oral dose, the maximum level occurring at the end of two hours.²⁸ It is readily and fairly rapidly excreted by the kidneys, and high concentrations of the agent occur in the urine.

The dosage recommended at present is the result of clinical experience gained thus far. When used orally, the initial dosage usually is 50 to 75 mg. per kilogram of body weight followed by 0.25 gm. every three or four hours (Fig. 473). In adult patients with peritonitis and other severe mixed infections, we have used 0.5 gm. every four hours effectively. The use of small or inadequate doses may increase the possibility of relapse. The duration of therapy may vary with the type and severity of the individual infection (Fig. 474).

Chloromycetin may also be administered parenterally by the subcutaneous or intramuscular route. Since the agent is relatively insoluble in



penicillin and ~~Sulfadiazine~~
chloromycetin therapy was good, but the long-term
evaluation.



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water, it has been administered in experimental animals in 20 or more per cent polyethylene-glycol solution. When administered parenterally, the effective dose is usually one fifth that of the oral. Until further experimental evidence is obtained, however, the parenteral injection of chloromycetin is not recommended for the treatment of human patients.

Laboratory Control.—No specific laboratory tests are recommended for the control of the administration of chloromycetin at the present time. Until more information regarding this agent is gathered, hemoglobin levels, blood counts and urinalyses may be used as safeguards.

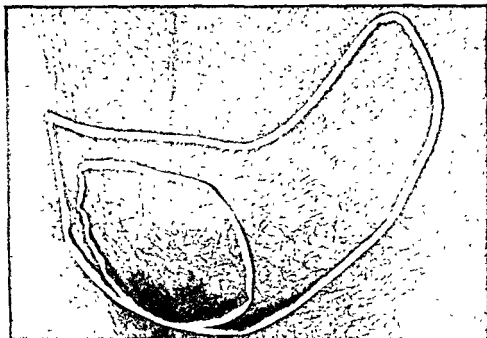


Fig. 475.—Illustrating the effect of chloromycetin in lymphopathia venereum. L.M., a Negro woman aged 35 years, was admitted to the Cincinnati General Hospital on March 8, 1949 with chronic lymphopathia venereum with large intra-abdominal granuloma and rectal stricture. Size of the large granulomatous intra-abdominal mass at start of chloromycetin therapy is delineated by white tape. Two weeks later the mass had become much smaller as indicated by smaller circle outlined by tape. At the end of four weeks the abdominal mass had disappeared and area of rectal stricture easily permitted passage of one finger.

Untoward Effects.—Chloromycetin is particularly remarkable as an antibacterial substance in that it has produced practically no toxic manifestations when administered either orally or intramuscularly within dosages of 50 to 100 mg. per kilogram of body weight per day. When it has been given orally to clinical patients, we have not noted nausea, vomiting or other signs of toxicity. The drug has thus far not produced sensitivity reactions, but it is almost inconceivable that this record continue indefinitely. Experimental animals given chloromycetin in this dosage have not shown significant changes in the total white blood cell

of differential counts, blood sugar levels, and liver function tests. Their use is maintained free of albumin and casts.

Clinical Indications.—Like aureomycin, the clinical potentialities of chloromycetin have not been fully explored as yet. Chloromycetin is very effective in the treatment of gram-negative bacterial infections, in mixed infections of wounds and the urinary tract, and in typhoid and typhus fever. Therapeutic response of chronic urinary tract infections to chloromycetin has been prompt, the urine usually becoming clear in twenty-four to thirty-six hours. When pyogenic coecal infections are also present in addition to the gram-negative infections, the use of penicillin or the streptomycins as therapeutic adjuncts is advised by some authors. Chloromycetin is considered that it is useful in the treatment of secondary infections of the genital tract, gonorrheal infections, pelvic inflammatory infections, gonorrheal proctitis, anacrobic streptococcal infections, and infections of the perineum (Fig. 175). Preliminary studies which I have made in the treatment of gas gangrene infections indicates that chloromycetin is effective in controlling the process. In the management of some gas gangrene infections produced by gram-negative bacteria, chloromycetin is more effective than streptomycin. Since it has little activity against the tubercle bacillus, however, it apparently is considerably less effective than streptomycin in the treatment of tuberculosis. In the treatment of the treatment of other virus or rickettsial infections, and in surgery have not been sufficiently explored to warrant discussion.

SUMMARY

Four new and effective antibacterial agents have been developed and made available for systemic and topical use. Of these, chloromycetin and aureomycin are unquestionably valuable antibiotic agents which will extend the field of antibacterial therapy, and increase its sphere of effectiveness. We have been particularly impressed in our clinical investigations with the low toxicity and clinical effectiveness of both agents in a wide variety of surgical infections.

Bacitracin is likewise a very effective agent, similar in its action in many respects to penicillin. Polymyxin holds a position in relation to streptomycin that is somewhat similar to that of bacitracin to penicillin. However, greater refinement and a means of eliminating the nephrotoxic effects will be necessary before it will be possible for either bacitracin or polymyxin to take their place with penicillin as really great antibacterial agents.

The successful management of surgical infections with any of these newer antimicrobial substances depends largely upon their correct use in relation to surgery and the application of the established principles of practical chemotherapy.

Although many other antibacterial agents are under study, none at this writing has reached a stage of development that will permit its

clinical investigation. Undoubtedly, however, surgery may confidently anticipate the introduction of more and effective agents in the future which will extend the field of usefulness of chemotherapy and aid in the control of hitherto resistant or refractive infections.

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ACUTE CRANIOCEREBRAL TRAUMA

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The correct management of acute head injuries constitutes one of the greatest challenges to present day surgery. The magnitude of the problem is such that it is not now and probably will never be possible for all such injuries to be treated by specialists in neurological surgery. It is essential, therefore, that all general practitioners and general surgeons have a clear understanding of the problem and be prepared to administer proper emergency treatment and to recognize immediately the danger signals that require the services of the specialist.

Much confusion and many contradictions have appeared in the literature with reference to the treatment of head injuries. We shall, in this contribution, attempt to clarify these treatment methods and, in addition, to review recent advances in the pathology and pathophysiology of acute head trauma.

PATHOLOGY AND PATHOPHYSIOLOGY

Skull fracture patterns do not follow the laws of mechanics because of the variations in shape, thickness and elasticity of individual skulls. The stresscoat technic used by Gurdjian and Lissner¹² has shown that there is a wide variation in the behavior of skulls subjected to trauma, but that there is a sameness noted in the direction of strain. Thus, for example, deformations of the skull due to occipital blows are far more severe than those resulting from frontal blows.

Skull fractures in themselves are of little importance except for the damage caused either directly or indirectly to the brain or to the cranial nerves. Fractures through the paranasal sinuses, the petrous portion of the temporal bone, and the mastoid cells are of special importance, since an avenue for meningitic infection is opened. Simple depressed and compound depressed fractures are of great importance because of the underlying brain damage. The brain scars thus produced are epileptogenic foci almost without exception, and clinical epilepsy develops in a high percentage of such patients unless proper treatment methods are employed.

Denny-Brown and Russell⁷ have shown that brain damage results from one of two mechanisms—*compression concussion* and *acceleration con-*

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concussion. Compression concussion is said to arise when the skull subjected to trauma is momentarily deformed and distorted even though not broken, and this distortion impinges on the brain, producing increased pressure in some areas and decreased pressure in others. The rebounding of the skull to its former shape results in abrupt changes in intracerebral pressure with damage to leptomeningeal vessels. Acceleration concussion, on the other hand, results from the momentum of the brain within the skull as the head is thrown through space and then abruptly brought to rest.

The ease with which lacerations of the brain occur when the brain is forcibly pushed against the irregular floor of the anterior fossa or the sharp edges of the greater wings of the sphenoid bone of the middle fossa of the skull is easily understandable. Lacerations of the tips of the temporal and frontal lobes produced in this manner are familiar findings at autopsy.

Pudenz and Sheldon²⁴ have shown in their ingenious experiments on monkeys with lucite skulls that blows to the head produce rotating, swirling movements of the convolutions of the brain, and these convolutional patterns vary with the direction of the displacement of the head. Midline frontal and occipital blows rotate the head through a sagittal arc, and the resulting convolutional glide is also in this same arc, whereas a complex arc of sagittal, horizontal and coronal glides is seen in temporal and parietal blows. Their experiments indicate that the frontal lobes of the brain are relatively fixed by the anterior fossa, and less movement occurs in them than in the parietal and occipital lobes. A similar situation exists with regard to the temporal lobes and their fixation in the middle fossa of the skull. This fixation of frontal and temporal lobes subjects them to greater shearing forces, and results in local laceration of cerebral tissue and blood vessels. These rotational glide observations explain the *contrecoup* injuries more logically than previous theories. Pudenz and Sheldon's²⁴ experiments are especially convincing since they are documented by high speed cinematography through the lucite calvarium.

For many years cerebral edema has been postulated as a frequent cause of death. In fact, the vogue of dehydration therapy resulted from the con-

ceded by intracellular hydration, stasis of blood, anoxemia of tissue, endothelial damage, etc.

Shapiro and Jackson²⁵ in a series of measurements of the water content of traumatized brains have concluded that although there is cerebral swelling, the increase in volume is caused by ventricular dilatation and venous engorgement. Windle, Groat and Fox²³ performed accurate determination of the water content in guinea pig brains using water-logged animals for controls, and showed brain edema after concussion to be slight. Rand and Courville²³ point out that swelling of the brain is due

to hydration of the cells themselves, or to excess fluid in the ventricular and subarachnoid systems. They feel that there is an increased secretion of cerebrospinal fluid due to an abnormal activity of choroidal and ependymal cells following trauma.

Scheinker²⁹ has repeatedly emphasized the importance of the term "cerebral swelling" rather than "cerebral edema." His concept of vasoparalysis, as first suggested by Friedman,¹¹ is the pathophysiological explanation of cerebral swelling. That there is a definite cerebral vasomotor control has been clearly demonstrated by Forbes and Wolff.¹⁰ Scheinker has elaborated upon this, and has suggested that following injury there is a paralysis of the cerebral vasomotor nerves resulting in vasoparalysis. The resultant stasis of blood flow produces anoxia of cerebral tissue, and cerebral swelling results from this as well as from venous engorgement. Diapedesis of blood results from the engorged veins as a result of the increased pressure and the effect of anoxia on the vascular endothelium. The white matter, because of its relatively poor vascularity, is involved to a much greater extent than the grey matter.

This increasing cerebral volume is of great importance clinically, for herniations of the uncus of the temporal lobes through the tentorium cause varying degrees of pressure upon the brain stem and hypothalamus—one of the most frequent causes of death in head trauma. Herniation of the brain stem produces engorgement of the vessels of the midbrain. It is this pressure effect upon the tegmental portion of the pons which produces decerebrate rigidity. The state of decerebracy is an ominous sign, and one which has usually in the past defeated all treatment methods.

Kahn¹⁶ has shown experimentally the disparity between intraventricular and cisternal pressure in water-logged animals. He consistently found an elevated intraventricular pressure and a normal or only moderately elevated cisternal pressure. His experiments indicate that transtentorial herniation had resulted in blockage of cerebrospinal fluid circulation at the incisura. He also found that decreasing intraventricular pressure improved the respiration and circulation, whereas decreasing cisternal pressure aggravated greatly the embarrassment of these vital functions. These observations are of extreme clinical importance, since lumbar puncture has been advocated by some as a treatment in cases of brain injury.

Cerebral concussion has been defined as "an immediate traumatic paralysis of reflex functions which occurs in the absence of visible lesions in the nervous system." Windle, Groat and Fox³³ feel that although gross pathological changes cannot be seen, there is a characteristic chromatolysis of neuronal cells following concussion. The present explanation for the phenomenon of concussion is that following trauma affecting masses of nerve cells, there results a depolarization of cell membranes. At the instant of impact there is an intense momentary excitation of the central nervous system, and following this, suprasegmental extinction of neural function results, thus causing loss of consciousness and changes in respiratory and circulatory activities. These symptoms may clear rapidly

and be followed by mild confusion, headache and unsteadiness, presumably as polarization of the cell membranes returns to normal.

DIAGNOSTIC CONSIDERATIONS

Early establishment of a clinical base-line in each case is essential in order that the future course of the patient may be evaluated. Records of the *temperature*, the *pulse*, the *respirations* and the *blood pressure* should be kept, for these vital signs are an invaluable index of function of medullary and midbrain centers. Nurses should be particularly warned that any significant change in these vital signs should be reported to the physician immediately.

Evaluation of the conscious level is of fundamental importance in prognosis and treatment. The classification of consciousness suggested by Botterell¹ is a useful one. He suggests the terms *coma*, *semicoma*, and *confusion* to describe the conscious levels. *Coma* denotes a state of absolute unconsciousness with no response to any form of stimuli. The activities which lie below the level of consciousness such as swallowing, pupillary reflexes and tendon reflexes, vary with each comatose patient and should be recorded. *Semicoma* is the state of unconsciousness in which the patient responds to painful stimuli, such as deep supraorbital pressure. *Confusion* denotes disturbance of consciousness characterized by inability to think clearly or respond accurately to situational stimuli. The degree of confusion should also be specified. Frequent checks should be made of the conscious level, for this one sign is probably the most accurate index of the patient's progress.

Scalp lacerations and contusions should be accurately recorded. Pulpified brain, or cerebrospinal fluid exuding from a scalp wound indicates severe laceration of the dura mater and brain tissue. *Cerebrospinal fluid leaks* from the nose or ears are positive evidence of fracture through the anterior or middle fossa with dural laceration. If by otoscopic examination a *bluish discoloration of the tympanic membrane* is observed, a fracture through the middle fossa of the skull is presumptive.

Observation upon the *size, reaction and equality of the pupils* is of fundamental importance in all patients suffering from acute head trauma. In fact, pupillary function is only secondary in importance to the state of consciousness in following the patient's progress. Fixed, dilated pupils are usually observed in only the terminal stages of brain injury. Small contracted pupils (unless the patient has previously received morphine) are seen in severe medullary damage and are, therefore, of serious significance.

Pupillary inequality with an impairment of light reflex both directly and consensually in the dilated pupil, is due to one of four conditions: (1) extradural hemorrhage; (2) herniation of the temporal uncus through the tentorium; (3) tearing of the oculomotor nerve from its origin in the brain stem; (4) direct injury of the nerve in the orbit by spicules of bone.

Classically, the *unilateral dilated fixed pupil* should be considered a

pathognomonic sign of extradural hemorrhage. It is usually seen on the same side as the lesion. The fact that in many instances this important localizing sign is caused by other lesions than extradural clot has caused some observers to question its value. From a practical standpoint, however, it should be assumed that *every patient with a unilateral dilated fixed pupil has an extradural clot until proven otherwise*. Operation in such circumstances is life saving, and procrastination means death; therefore, we believe that every physician treating traumatic head cases should accept the thesis that progressive unilateral dilatation and fixation of the pupil is pathognomonic of extradural hemorrhage—even though there is a taint of dogma in the teaching.

Ophthalmoscopic examination is important in that *progressive choking of the optic disks* indicates a severe degree of increased intracranial pressure. An unequivocal "choked disk" probably requires several days to develop, but venous engorgement, retinal hemorrhages, blurring of the disk margins, and obliteration of the normal landmarks of the disk are valuable signs in determining the degree of intracranial tension.

Facial nerve function is of importance only in detecting hemiplegia or hemiparesis. In the semicomatose or confused patient, one may stimulate grimacing by supraorbital pressure or other forms of painful stimuli, and thus evaluate function of the facial muscles. In the comatose patient, some reliance can be made on the finding that the cheek on the paralyzed side blows out with respiration more markedly than does the cheek on the normal side.

The *motor power of the extremities* may be judged in one of several fashions. If the patient is confused and restless, one may observe directly the manner in which the extremities are used. If in semicoma, deep supra-orbital pressure will elicit a defense reaction of one or both arms and thus their strength may be judged with considerable accuracy. Some information can be gathered by observing the tonicity of the musculature in passive flexion and extension.

One frequently sees *Babinski's sign* either bilaterally or unilaterally following severe head trauma, but unless paralysis is present, this pathological reflex usually disappears as the cerebral function improves.

Roentgenograms of the skull and their importance in the early hours of head trauma is a moot question. It is the authors' opinion that satisfactory x-rays are of considerable aid, but the difficulty in obtaining them when the patient is confused or disoriented far outweighs their importance. Roentgenograms during the acute stages of head trauma are only of major importance in demonstrating depressed fractures of the skull or linear fractures crossing the groove of the middle meningeal artery. We believe that the clinical signs will serve as an adequate guide in almost every instance until such time as the condition of the patient permits careful radiographic examination.

The value of *lumbar puncture* in acute head trauma, both diagnostically and therapeutically, has been greatly overemphasized. The dangers of lumbar puncture in infratentorial mass lesions were clearly demon-

strated by Harvey Cushing.⁴ The dangers in supratentorial lesions are not fully appreciated, even by neurosurgeons. Swelling of the cerebral hemispheres due to venous stasis and cellular edema produces an ideal set of physical conditions for herniation of the temporal uncus into the incisura of the tentorium. Sudden release of infratentorial pressure by lumbar puncture aggravates the unnatural pressure relationship and must be considered a potential danger in precipitating or aggravating tentorial herniations.

Lumbar puncture for measuring intracranial pressure has been advocated by many authors as being a valuable diagnostic adjunct in head trauma. In restless,

of the tentorium has occurred, the pressure below is no index of the pressure above the tentorium because the free flow of fluid through the incisura has been impeded. In such circumstances, only the intraventricular fluid pressure would give an accurate index of the supratentorial pressure

TREATMENT

Inflexible routine treatment of patients suffering from head trauma is not only useless but dangerous. No other group of surgical patients demand such individual consideration. Alert, watchful care is perhaps the most important feature. Since the patient's condition may vary from hour to hour, continuous efficient nursing care is of prime importance. For sake of convenience, this section on treatment is divided into (1) general care and (2) conditions requiring operative intervention. The principles for the general care of the patients who are not operated upon apply equally well to those in whom operative intervention is indicated

GENERAL CARE

Establishment of an unobstructed airway should be the initial effort in the treatment of any unconscious or semiconscious patient. The brain is very susceptible to anoxemia, and irreparable damage may result in a short time unless oxygen in adequate supply is provided and maintained. *Postural drainage* as an efficient method of combating airway obstructions in the unconscious patient was first advocated by Coleman.⁴ This has proved to be one of the greatest advances in the treatment of head trauma of recent years. The patient is placed in the head-down position and turned on his side so that secretions from the trachea and nasopharynx drain by the force of gravity. This position is of particular importance in profoundly unconscious patients when the swallowing reflexes have been abolished. The secretions may be so tenacious that the force of gravity is not enough to remove them. In such circumstances, a suction apparatus attached to a soft rubber catheter is most helpful.

Once an adequate airway has been established, it is our belief that oxygen should be administered to every unconscious patient. The tent method is preferable but the nasal catheter technic is adequate.

Shock.—The symptoms of traumatic shock are observed infrequently in uncomplicated cases of head injury. As a matter of practical importance, if the patient arrives in a state of shock, one should be careful in seeking for other injuries—a broken neck, a fractured femur or a ruptured viscus. Hemorrhagic shock not infrequently occurs from extensive scalp lacerations which have not received early treatment.

Hyperthermia.—The hypothalamic centers are particularly susceptible to trauma and the heat regulating mechanism is frequently upset. When the body temperature exceeds 104° F. rectally, it is most important that every effort at one's disposal be used to reduce it. The time-honored custom of keeping the patient covered with blankets, even though his temperature may be 106° F. should be discarded once and for all. When combating hyperthermia, it is essential that all bed clothing be removed, the patient's body be sponged with tepid water or alcohol and a gentle breeze be created with electric fans. In severe cases, it is desirable to cover the patient with wet towels, using electric fans to dry them. In addition to these physical measures, small doses of morphine sulfate, $\frac{1}{4}$ to $1\frac{1}{2}$ grain, repeated every two hours, are sometimes effectual in combating hyperthermia.

Restlessness.—Extreme restlessness is a disturbing early complication of head trauma. If it is only of mild degree, simple nursing measures are sufficient. When extreme, it becomes necessary to use sedative drugs. Paraldehyde is by far the best and safest drug to quiet the restless patient. It may be given by mouth, by rectum or even intravenously.

The barbiturates are usually not satisfactory because they may excite the patient rather than quiet him. Morphine in conventional doses should never be used because of the depressing effects upon the respiratory centers. Physical restraint of the restless patient should always be avoided if possible. Too many times restraining measures only add to the combativeness of the restless patient.

Fluid Intake.—The maintenance of a normal fluid intake is essential. The dehydration treatment, so popular a decade ago, has, for the most part, been abandoned. The objective of the dehydration treatment was to prevent cerebral edema. This conception now appears faulty because it is probable that cerebral edema does not depend upon the normal fluid requirement of the body.

The average size adult should receive between 2500 and 3000 cc. of fluid in twenty-four hours to maintain a normal state of hydration. In exceedingly warm weather the level should be 1000 to 1500 cc. more. It must be remembered that the restless irritable patient will rapidly dehydrate himself unless an adequate fluid intake is maintained. Fluids are administered intravenously for the first two or three days of unconsciousness. Our routine is to use 1000 cc. of 5 per cent dextrose in normal saline, 1000 cc of 5 per cent dextrose in distilled water and 500 to 1000 cc. of

protein solution each twenty-four hour period. If unconsciousness prevails after three days, we recommend the insertion of a nasal tube through which fluids and nourishment are given every six hours. The only contraindication to the nasal tube is the presence of a cerebrospinal fluid leak from the nose or nasopharynx.

Nourishment.—Adequate nourishment is always a problem in the unconscious patient. Intravenous dextrose is adequate for a day or so, but if the unconsciousness persists, protein deficiencies develop rapidly. *A basic caloric and vitamin intake should be maintained throughout the illness.*

Oral Hygiene.—Oral hygiene in an unconscious patient is of great importance and failure to observe it may result in parotitis or parotid

vents drying and cracking of the mucosa.

Urinary Incontinence.—In all unconscious patients from head injury, urinary incontinence becomes a problem. If the patient is not too restless, soiling of the bed may be avoided by the simple expedient of placing a urinal between the leg continuous drainage of catheter *Urinary tract*

bladder irrigations and minimal doses of one of the sulfa drugs.

Chemotherapy.—Every patient with scalp lacerations or with fractures involving the paranasal sinuses or middle ear, with or without cerebrospinal fluid leaks, should receive chemotherapy. Also, it should be administered to profoundly unconscious patients in order to reduce the incidence of aspiration pneumonia. We consider penicillin in the usual therapeutic doses to be sufficient in all circumstances unless there is a

brospinal fluid in concentrations sufficient to reduce the probability of meningitis.

CONDITIONS REQUIRING OPERATIVE INTERVENTION

In almost every case of craniocerebral trauma, one of the most important considerations from the beginning is whether surgical intervention is indicated. In spite of the voluminous literature of the past decade on conservative treatment measures, the experienced physician is ever aware of the tragedies of surgical lesions going unrecognized until the patient is moribund. It is true that not one patient out of five requires any type of surgical operation; yet, it is the recognition of that 20 per cent that constitutes an ever perplexing problem.

Gunshot and Missile Wounds of the Brain.—These lesions are of the greatest importance in time of war but occur relatively infrequently in

civilian practice. They constitute a special problem, and their rarity in civilian life hardly justifies the space required to make an adequate presentation here. Furthermore, the subject has received thorough treatment in a small monograph recently published by Matson.¹⁸

Depressed Fracture of the Skull.—When the head is struck by a relatively small rapidly moving object (i.e., hammer, pistol butt, monkey-wrench, bottle or the flying heel of a mule) the skull is bent inward until it breaks, and a depressed "eggshell" fracture results. The scalp may or may not be broken at the site of impact; if it remains intact a "simple depressed" fracture results. If the scalp is lacerated through the pericranium a "compound depressed" fracture results. Whether simple or compound the indications for surgical repair of the depressed bone fragments are clear. Depressed fractures are usually associated with localized brain laceration or contusion. Prolonged loss of consciousness is the exception rather than the rule.

Treatment of this type of head injury is purely mechanical. The scalp wound should be thoroughly débrided, the broken pieces of bone removed, the torn meninges carefully repaired, and the contused, devitalized brain removed cleanly with suction. Unless débridement is complete a corticomeningeal scar will form and sooner or later will act as an epileptogenic focus. Such patients are always potentially active epileptics (traumatic epilepsy).

Débridement should be started from without inward; the scalp, the skull, the meninges and finally the brain. The repair of the dura mater is an important step. Unless a tight closure can be accomplished by approximating the torn edges, a dural graft of the pericranium should be used. The bone defect may be repaired primarily or secondarily with a tantalum plate. The older practice of saving the bone fragments and attempting to prop them against each other to repair the defect is never recommended. Cranioplasty with tantalum or one of the acrylic resins has proven highly satisfactory in thousands of war injuries and is rapidly replacing the usual bone graft technic in civilian clinics.

Simple depressed skull fractures require surgical repair in most instances because of the underlying brain damage. Electroencephalography is an important aid in determining which of these cases should be operated upon. If abnormal waves are found beneath the fracture site, the fractured skull should be repaired. If the tracings are normal and the skull fragments are depressed but slightly, then surgical intervention is not indicated.

Extradural Hemorrhage.—Of all the serious complications of head trauma, extradural hemorrhage should be the easiest to recognize and the most satisfactory one to treat. Yet, in most of the large clinics the mortality from this lesion varies from 30 to 50 per cent! Three factors are responsible for these unbelievably bad statistics: first, failure in diagnosis; second, delay in operation once the lesion is suspected; and third, the frequency of severe associated injuries.

The classic symptoms of extradural hematoma are as follo

tient is dazed or rendered unconscious for a few minutes by a blow on the head. He may recover completely or may complain of headache, perhaps nausea, or a feeling of faintness, at any rate, he usually becomes rational for a while after the blow (lucid interval). Within an hour or so his mental faculties become dull and he feels drowsy. Sleep steadily progresses to coma, with stertorous breathing. The pulse becomes slow, and the blood pressure is elevated.

There is usually puffiness or soft induration of the scalp and temporal muscle in the vicinity of the blow to the head. The pupil on the injured side is usually larger than normal and may be widely dilated and fixed. The contralateral arm and leg may be weak, and a positive Babinski response may be present. Occasionally, Jacksonian convulsions may occur.

If films of the skull have been made immediately following the injury, it is usually found that there is a linear fracture in the temporal fossa, the fracture line usually passing across the middle meningeal groove.

An extradural hematoma usually arises from laceration of the middle meningeal artery, but any of the meningeal vessels or even the dural sinuses may be torn and thus produce an extradural clot either over the cerebral hemispheres or over the cerebellum.

Like any other clinical syndrome, all the classic signs and symptoms of extradural hematoma are not invariably present. For instance, the patient may never regain consciousness after the blow—an occurrence frequently seen when there is severe associated brain injury. The lucid interval may be prolonged, in fact, the first sign of extradural clot may occur several days after the original trauma. The unilaterally dilated fixed pupil may be absent particularly if the bleeding comes from the anterior or posterior meningeal vessels. These variations do occur, but the classic syndrome of extradural hemorrhage is more constant and the pattern and sequence of symptoms more exact than in most other clinical entities.

Mortality statistics from extradural hemorrhage will improve when earlier diagnosis becomes the rule and when skillful surgical intervention is provided early once the diagnosis has been made.

Early diagnosis cannot be expected until every physician—even those who care for head trauma patients only occasionally—knows these early symptoms and signs. Since it is impractical to hospitalize every patient who has been unconscious for a short period, the attending physician should sit down with a responsible member of the family and painstakingly explain the early danger signs of this dreaded complication. *No patient who has been unconscious from a head blow should be allowed to sleep longer than two hours during the first night without being aroused.* This is the only way to distinguish between normal and pathological sleep.

The next improvement must come with earlier treatment. This is one lesion in which the sleepy, attending surgeon cannot tell his house staff to "watch the patient carefully and I will see him the first thing in the

morning." When the classical signs and symptoms are present, *operate without delay*. When the signs are suggestive but not positive, burr hole explorations are indicated if the patient's condition is deteriorating.

Acute Subdural Hematoma and Intracerebral Hematoma.—Brain injuries sufficient to produce laceration of the cerebral substance with hemorrhage occur frequently. Such injuries are usually *contrecoup* and, as has been indicated under the pathological section of this paper, are almost entirely in the frontal and temporal lobes. Usually the acute subdural hematoma is a relatively small one and probably represents only a small part of the lesion. However, when intracerebral bleeding occurs, the hemorrhage may be of large proportion, consisting either of laked or clotted blood.

All too frequently patients with such lesions are moribund when they arrive in the hospital. However, in a patient showing progressively deepening coma and a change in vital signs, indicating increased intracranial pressure, or evidence of progressive neurological dysfunction, intracerebral bleeding should be suspected and burr hole exploration made. It is often impossible to distinguish between extradural, subdural or intracerebral hematomata preoperatively. The differentiation of them is of academic interest only, for all three lesions demand prompt surgical exploration.

Chronic Subdural Hematoma and Hygroma.—The classification of acute and chronic subdural hematoma is not a particularly satisfactory one. Acute hematomas are usually associated with cerebral laceration and more diffuse brain injury; whereas, chronic hematomas may result from minimal injury and with little or no actual cerebral damage. A slow progress of the latter is the determining factor. The pathology of chronic subdural hematomas postulates tearing of the veins bridging the cerebral cortex to the sagittal sinus. Pudenz and Sheldon²⁴ observed tearing of these vessels visually through the lucite calvarium in monkeys. It is logical to assume, therefore, that any condition that gives rise to a greater gap between the sagittal sinus and the leptomeningeal attachment of these veins will add to the likelihood of these lesions, i.e., cortical atrophy from alcoholism or the usual vascular changes of old age.

Laceration of veins as they traverse the subdural space permits an accumulation of blood in the space to the point where the venous pressure and the pressure within the hematoma are equal. At this point no further bleeding occurs. The arachnoid acts as a semipermeable membrane and thus permits cerebrospinal fluid to enter the subdural space by dialysis, since the protein content of the hematoma is much greater than that of the cerebrospinal fluid. The expanding subdural hematoma is progressively encapsulated by a membrane of mesothelial cells.

The symptomatology of chronic subdural hematoma is frequently not distinguished from that of brain tumor. The trauma may have been so inconsequential that it had been overlooked by the patient or his family. The major complaints are those of increasing headaches and mental dullness progressing to somnolence. Convulsions or hemiparesis may

develop. The usual signs are those of increased intracranial pressure such as papilledema, slowing of the pulse rate, and gradual increase in the systolic blood pressure.

In most instances the lumbar spinal fluid shows an increase of intraspinal pressure and characteristically the fluid will be slightly xanthochromic.

Whenever a subdural hematoma is suspected, bilateral burr holes should be placed in both superior temporal regions. A bluish discoloration of the dura mater is a characteristic finding. Evacuation of the hematoma with thorough lavage of the interior of the limiting membrane is all that is required to effect a cure. Occasionally, the hematoma will be found to be solidified with clots, and it will be impossible to remove it through exploratory burr holes. In such circumstances, the usual osteoplastic bone flap offers the only solution to the problem. It cannot be emphasized too often that these lesions are frequently bilateral, and when one is suspected, *bilateral burr holes must always be made without exception.*

Subdural hygroma is a lesion which closely simulates a true subdural hematoma. The lesion is presumably caused by a small tear in the arachnoid which allows cerebrospinal fluid to escape into the subdural space. The small opening in the flimsy arachnoid acts as a "ball-valve" permitting cerebrospinal fluid to escape into the subdural space but not permitting it to return to the subarachnoid space. Restlessness, coughing, sneezing or a convulsion will force fluid in relatively large quantities into the subdural space through a very small tear in the arachnoid.

The clinical symptoms are similar in every respect to subdural hematoma. The lesion occurs with all grades of head trauma, therefore, the clinical symptoms associated with the lesion vary from patient to patient. It should always be suspected when an otherwise smooth convalescence is interrupted by signs of increasing intracranial pressure.

The treatment is the same as for chronic subdural hematoma.

Persistent Cerebrospinal Fluid Rhinorrhea. The danger of persistent cerebrospinal fluid rhinorrhea has been stressed. The rhinorrhea occurs as a result of dural laceration accompanying fracture through the anterior fossa, and is usually unilateral. It can be readily demonstrated when the patient tilts the head forward, the clear fluid dripping from the nose drop by drop.

In the majority of instances, spontaneous cessation of the rhinorrhea occurs. If it still persists after seven to ten days, operative intervention is indicated. Vigorous prophylaxis with sulfadiazine and penicillin should be made both preoperatively and postoperatively.

Adequate visualization of the anterior fossa by x-ray is difficult, but usually stereoscopic views through the optic foramina will demonstrate the fracture site.

The repair is accomplished through one or two frontal osteoplastic flaps. If the fracture site can be lateralized, a small frontal bone flap

will suffice. If not, a bilateral bone flap may be required. The anterior fossa should be explored extradurally until the fracture site is identified. It may not be possible to demonstrate accurately the dural laceration, and not infrequently when demonstrated, it is impossible to suture the tear without excessive damage to the frontal lobe. All that is usually required to effect a cure is to place a large graft of fascia lata, previously removed from the patient's thigh, over the anterior fossa to separate completely the fracture from the dural laceration.

Tentorial Herniations.—The development of decerebrate rigidity arises as the result of a mass cerebral lesion producing tentorial brain stem herniation. This condition may occur whenever the intracranial tension above the tentorium is greater than below it, particularly when the increase of pressure is rapid. Extradural hematoma, subdural hematoma, intracerebral hemorrhage and cerebral edema are frequently complicated by tentorial herniations. But whatever its cause, it is a serious complication, the effective treatment of which has never been fully established. When a mass lesion is demonstrated at operation and its removal accomplished, pressure relationships are soon equalized and the herniation reduces itself spontaneously. However, if there is a mass lesion in one temporal or frontal lobe associated with unilateral cerebral swelling, satisfactory methods of combating it have not yet been agreed upon. Scheinker²⁹ has suggested ventricular puncture and slitting of the free edge of the tentorium as two possible corrective measures. The former is of doubtful effectiveness, particularly when the ventricle is small. The second is an operative procedure of great magnitude, one hardly suitable for a desperately ill patient. Vincent and LeBeau³¹ describe a method of manual reduction of the uncal herniation. Their approach is through the temporal region and consists of gently elevating the temporal lobe until the tentorial notch is reached. The herniated convolution is reduced manually and lifted upward and backward. They record immediate improvement of symptoms following this procedure in certain cases.

We believe that Botterell¹ has made the most important contribution to this phase of operative treatment of serious head trauma. His method consists of removing the pulpified brain in the temporal or frontal area with suction, thus providing an internal decompression. It is his belief that by removing this useless pulpified brain tissue the cerebral swelling is discouraged. His approach is on the inferior and medial surface of the temporal lobe; therefore, dangers of sacrificing centers of vital cortical function are practically nil. Since these areas of localized brain damage are frequently associated with intracerebral accumulations of blood, this procedure appears to be a logical one, for this not only affords the most accessible approach for intracerebral clots but permits one to remove the damaged brain tissue and control all of the bleeding vessels in the immediate vicinity.

Since the temporal lobes are most frequently lacerated, the approach should first be directed toward this area. If, after dealing adequately

with the traumatized area, the intracranial tension is still high, then the traumatized frontal pole is dealt with in exactly the same manner.

This is surgery of great magnitude and should not be attempted unless one is prepared with all the modern neurosurgical facilities to affect perfect hemostasis. Internal decompressions of this sort should be considered in all patients who are showing progressive deterioration from brain stem strangulation.

SUMMARY

Recent contributions in neurophysiology and neuropathology pertinent to craniocerebral trauma are reviewed. The diagnosis and treatment of head injuries are discussed, and an attempt made to clarify controversial points which have appeared in the literature.

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RECENT ADVANCES IN THE SURGICAL TREATMENT OF INTRAORAL CANCER

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The treatment of intraoral cancer has been almost entirely by methods of irradiation since the effects of roentgen and gamma rays on tumor tissue were first demonstrated. Progress in the application of radiation to intraoral cancer has been steady, and great strides have been made up to the last few years. At the present time, however, it would seem that an impasse has been reached, a point at which no new techniques are being developed and where the end results of known methods have all achieved a monotonous standardization. The average over-all salvage rate for intraoral cancer, excluding lip lesions, is around 25 per cent, certainly not more than 30 per cent. These are dismal figures when one considers that these tumors are situated in one of the most accessible areas of the body. End results for cancer of the skin, uterus, cervix and rectum are much better in these comparably accessible sites.

Even in selected series of "early" intraoral cancer the showing is not satisfactory, failure rates of 45 per cent being the lowest reported. These considerations have initiated a re-evaluation of the possibilities of surgical attack. These possibilities have been greatly enhanced by the perfection of intratracheal anesthesia, the development of antibiotics, and by more complete understanding of the problems of shock, fluid balance and maintenance of circulating blood volume. Due to these advances in the ancillary surgical sciences, we are now in a much better position to explore more fully the potentialities of surgical attack.

INDICATIONS FOR SURGICAL TREATMENT OF INTRAORAL CANCER

Lip Cancer.—There is no absolute contraindication to surgical treatment of cancer of the lip, as far as the local anatomic and tumor problem is concerned. There is, however, a wide range of lip cancers that can be equally well treated by adequate irradiation. There are two stages of lip cancer where surgery would seem to be the treatment of choice, the very early, and the very advanced and extensive problem.

It is our practice that no patient is treated by irradiation without a biopsy positive for cancer. In the extremely early lip cancer, where adequate biopsy will practically remove the lesion, an "excisional biopsy" may as well be done, removing the tumor completely so that there is no need for irradiation.

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In this regard, there is one aspect of lip cancer that has allowed, to us at least, a new approach. There have been a fair number of patients with "early," very superficial, carcinoma of the lip which nevertheless occupies a rather wide surface area. These tumors appear as crusting plaques, occasionally with ulceration, situated in areas of leukoplakia and thickening of the vermillion border. Some of these areas of cancer and precancerous epithelial change occupy such a wide transverse expanse that a classic V-excision would remove the entire lower lip, an obviously unnecessary sacrifice of tissue. Microscopic examination of serial sections of such lesions will often show multiple separate islands of invasive carcinoma interspersed in benign epithelium. Such tumors can be most simply removed by elliptical transverse incisions, excising completely all involved epithelium, with a minimum loss of substance of the lip. The mucosa of the inner surface of the lip is then undercut and brought forward to the skin to reconstitute the vermillion border. Approximation of the two edges with fine interrupted sutures will leave an almost undiscernible scar and literally no asymmetry or cosmetic defect. Such a procedure allows maximum removal of involved mucosa. By "involved mucosa" is meant not only declared carcinoma but also the irreversible precancerous changes of atypical hyperplasia from which new cancers or "recurrences" may arise. This problem of multicentric origin is more common and of more importance than is generally realized. Radiation does not seem to eliminate the precancerous changes, but surgical removal would seem to eliminate such a tendency in the area excised.

The very extensive lip cancers furnish an obligate indication for surgery, unless only palliation is intended. These large, fungating, extensive lip cancers have a somewhat different natural history than the average tumor of this location. They are of longer duration, slower growth, and have a much lower percentage of cervical node metastases than do smaller and more rapidly growing tumors. Likewise they are more differentiated histologically, and less radiosensitive. These tumors afford a great temptation to try radiation therapy, because of the seemingly brutal extent of surgery and plastic repair involved. They nevertheless are surgical problems, as irradiation usually results in failure. They probably represent a form of "verrucous carcinoma," a highly radioresistant type of intraoral cancer described by Ackerman.¹

There is a final indication for surgical treatment of lip cancer which may seem philosophical but actually is of very real practical importance. This is, relative youth. The effects of x- and gamma radiation are both permanent and progressive, and in a patient with twenty to forty years' life expectancy, the late effects of cancerocidal doses of radiation may be very serious and even disastrous. This is of timely importance now, because of the increased frequency of lip and skin cancer appearing already in veterans of World War II, due to overexposure to sunlight, particularly in the South Pacific areas.

Leukoplakia.—Leukoplakia in the mouth is essentially either a

medical or surgical problem. There has been much discussion of its precancerous attributes, but little definite information has been recognized. Leukoplakia occurs in many stages of maturation, and is associated with several accompanying pathologic states, such as avitaminoses, hepatic disease, Plummer-Vinson syndrome, syphilis, and other unrecognized but probably metabolic diseases. Local irritation is a very important factor, but appears to be so only in individuals with a vulnerable oral mucosa. These individual variations cannot be predicted at the present time.

For practical purposes, leukoplakia may be regarded in two categories, the reversible and the irreversible. Thin, filmy leukoplakia is of no great consequence and can be reversed toward the normal by medical measures, mainly by avoidance of irritation from tobacco. It is probably true that most leukoplakic areas may be made to regress by medical management if it is started very shortly after the inception of the visual epithelial change.

Persistent and long-standing leukoplakia, however, particularly if it is palpable, is a significant lesion. After medical management has produced all regression possible, residual leukoplakia should be destroyed, either by excision or cautery destruction. There is no question in our minds about the precancerous qualities of irreversible leukoplakia. Whether or not cellular atypia can be demonstrated on biopsy at a given moment, the danger of the eventual development of cancer from this epithelial change is so great that all such areas should be destroyed. Electrocautery destruction is the usual means, but excision of small or linear areas, and suture repair, are often possible, particularly in the tongue or cheek. Radiation seems to have no part in the treatment of leukoplakia. The differential of radiosensitivity of this lesion as compared with that of normal mucosa is so slight that the use of radiation is unwarranted. The authors have repeatedly seen leukoplakia occur in the exact center of a healed radiation mucositis, where a cancerocidal dose of x-ray had been given previously for epidermoid carcinoma.

One of the newer concepts of the growth mechanism and reasons for the poor cure rate of intraoral cancer is the concept of multicentric origin.² It seems probable that many such carcinomas arise from multiple foci of origin in a field of preconditioned epithelium. These foci may or may not be related microscopically, but the occurrence of multiple primary carcinomas in the mouth is an unquestioned problem. The following case history is an illustration of the interrelated problems of precancerous leukoplakia, multiple cancers, and the progressive maturation of persistent leukoplakia into new tumors.

CASE I (Fig. 476).—The patient is a 61-year-old male.

He is a long-term diabetic. A cancer of the tongue was removed in 1947. In 1947 he had an ulcer of the size of a dime. There was leukoplakia on the tongue and in the right buccal mucosa. A suspicious node in the right submaxillary area was noted. The ulcerated lesion was excised and found to be epidermoid carcinoma. Because

the leukoplakia was so extensive it could not be excised and only the more keratinized areas were coagulated. During the next few months the leukoplakia was periodically observed for significant changes. Minute fissures and ulcerations in the leukoplakia were observed to come and go. However, in January 1918 a painful ulceration in an area of leukoplakia behind the commissure of the right upper lip was excised and found to be carcinoma. The area had shown a persistent

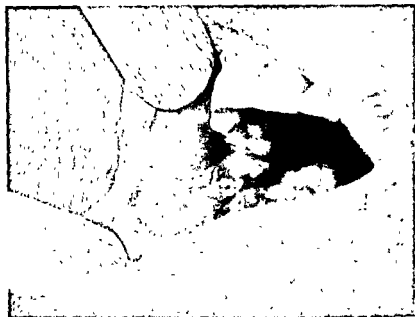


Fig. 476—Extensive leukoplakia of buccal mucosa. Patient in Case I

developing new carcinomas in areas of preconditioned leukoplakia, it was elected to perform only an upper neck dissection.

In January 1919 a firm area of ulceration in leukoplakia of the right buccal

cancer, but probably only for a short period of time.

This case well illustrates the concept of multicentric origin of tumors. Five individual carcinomas had arisen from separate areas of preconditioned epithelium. In cases of diffuse leukoplakia it is felt that local excision of the carcinoma as it arises is the treatment of choice when possible. It is simple, quick, effective and of minimal discomfort to the patient. It avoids the possibility of overlapping or compounding tissue injury from repeated x-ray exposure.

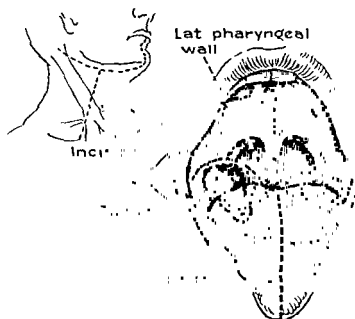
Early Intraoral Cancers.—There is a trend back toward surgical management of intraoral cancer because of the rapidity of healing and the short-term morbidity from a cleanly healed surgical wound as compared with the weeks of mucositis from radiation. These considerations are particularly applicable to the very early intraoral lesions where an "excisional biopsy" may as well be done as biopsy followed by radiation. This is especially true of tumors of the anterior and lateral border of the tongue. One great advantage of surgery over x and gamma radiation is that only the tissues excised, and the immediate edge of the repair, are damaged or even affected by the treatment. Infection, even in the mouth, is a rare complication today. With radiation, however, of the type used for cancer therapy, there is inevitable and unavoidable damage and permanent change in normal tissue well beyond the area of the tumor. Although this effect can be minimized by modern irradiation technics, it cannot be eliminated. This change in normal tissues, and the permanent and progressive character of radiation effects on tissue, again makes youth a relative contraindication to irradiation of intraoral cancer.

Cancer of Tongue.—Cancer of the tongue also is being treated more and more by surgery primarily. This is perhaps due simply to dissatisfaction with the accomplishments of irradiation, and it is too early yet to evaluate the results of the more aggressive surgical approach. It should at least be fair to predict that the salvage rate from surgery can be no worse than that from irradiation. There is one aspect of tongue cancer in which there is fairly general agreement as to the indications for surgery. That is the association of tertiary syphilis with squamous cell carcinoma of the tongue. The results of irradiation in this group are execrable, and it is almost universally conceded to be a surgical problem. Since about 30 per cent of all patients with tongue cancer have tertiary lues, this constitutes no small segment of the over-all picture.

Cervical Node Metastasis.—No outline or plan of treatment for intraoral cancer can be complete without consideration of cervical metastatic disease. The consensus is that radical neck dissection is the procedure of choice for cancer metastatic in the cervical lymph nodes. No new technics have been developed, however, except in the combined operations, which will be discussed later. The methods, indications and timing of neck dissections have been stated elsewhere.^{3,4}

Advanced and/or Recurrent Intraoral Cancer.—The major advances in the surgical management of this intraoral cancer have come in a group of patients with extensive disease. Two types of clinical problems especially have been benefited. These are recurrent cancer following maximum radiation dosages, and squamous cell cancer invading the jaw-bone, whether or not it has been irradiated previously. These two problems have formerly been considered hopeless and all such patients have died of their disease except an occasional lucky one. In many of these patients there is cervical metastatic cancer which has compounded the problem to an impossible degree.

A much more aggressive and logical surgical approach has been developed which has salvaged some of these unfortunate individuals. This is the operation of the combined neck dissection with resection in continuity of the mandible with the involved intraoral soft parts. The basis of the technic was devised by Bloodgood in his operation of partial neck dissection and external resection of the mandible along with the intraoral cancer. Today this procedure has been expanded to comprise a radical neck dissection, with removal of the internal jugular vein and sternomastoid muscle, excision of the hemimandible and removal of the attached cancerous intraoral tissues. The entire procedure is



done "in continuity" as an "en bloc" removal. A temporary tracheotomy should always be effected with this procedure.

Such an operation was not possible without a prohibitive mortality rate until the perfection of intratracheal anaesthesia and the development of antibiotics. Today the postoperative loss is reasonable and we have performed thirty-two such operations with the surgical loss of two patients, both sudden cardiac failures, one on the eighth day in a patient almost ready to go home, and one on the second day in an 86 year old woman. Both patients were doing well up to their sudden expiration, and neither death was predictable, except that the latter could hardly be considered an odds-on favorite for survival.

This combined operation, as outlined, is logical because squamous

cell carcinoma is not an aggressively angio-invasive tumor. It metastasizes mainly by way of the lymphatics, to the head and neck area. It usually kills before the tumor has spread below the clavicles, so that distant metastases to lungs, liver and bones are not a limiting consideration.

The technic of the modern "combined operation" has been developed mainly by Martin and his associates on the Head and Neck Service at the Memorial Hospital in New York City.⁵ They have the largest series

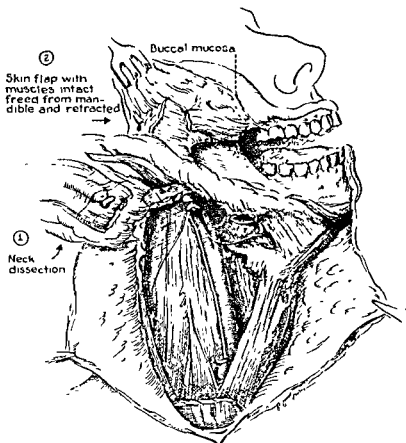


Fig. 478.—A completed radical neck dissection left attached to the mandible. The carotid artery, vagus, phrenic, accessory and hypoglossal nerves are preserved. The cheek flap is reflected upward exposing the mandible.

of such operations to date Grant Ward has recently reported⁶ on his own series, in which the first case was done twelve years ago. Both series have some patients who have survived five years free of disease. Our own longest survivors have reached forty-two months at the present writing.

It is apparent that some previously hopeless patients can be salvaged by this technic. This being true, it would seem that the application of this procedure to earlier cases of intraoral cancer should in the future improve the present low over-all cure rate.

Technically the operation consists of a formal radical neck dissection up to the inferior edge of the mandible. The lip is then cut in the midline into the mouth and the mandible is sectioned with a Gigli saw at the symphysis and swung outwards. The soft parts are excised as necessary, a hemiglossectomy being done if required. Posterior tumors involving the palate can be removed up to the midline. The hemimandible is disarticulated if it is invaded by tumor or if the lesion is well posterior, otherwise only the horizontal ramus need be resected. Repair is by suture of the medial cut edge of the intraoral soft parts to the mucosa of the cheek flap in two layers if possible, with interrupted catgut. The skin flaps are easily approximated and drained. (See Figs. 477 to 480.)

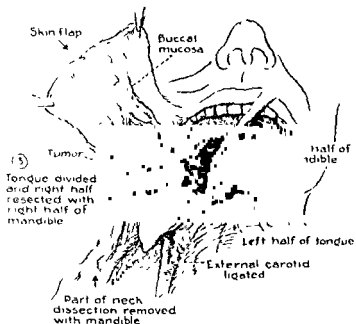


Fig. 479.—The mandible and tongue with its contained tumor have been divided. Disarticulation of the mandible frees the en-bloc tumor mass.

The cosmetic and functional defects from such a procedure are less than one would anticipate. The patients have been those with advanced disease, usually in older age groups, and they are so much better off after the procedure than before that they almost invariably refuse secondary operative reconstruction. They are able to maintain and gain weight, and pain is eliminated by the operative section of the cervical plexus and third division of the fifth nerve. Most of them have been restored to economic independence and are working daily. In these patients with advanced intraoral cancer, any salvage in terms of survival time free of disease is real and not relative. They have nothing to lose and everything to gain. We are not in a position to quote survival rates from our own series, but it is apparent that many of these patients can

be totally salvaged. Since the salvage rates from traditional treatment of intraoral cancer are so low, it is obvious that there must be many of these instances of advanced or recurrent intraoral cancer in which such an operation would be applicable.

CASE II—The patient is a 62 year old white male admitted to the Presbyterian Hospital on January 18, 1947. Two years previously, he observed a "sore" in his left inferior alveolar gingival gutter. He consulted his physician who advised him to have the area treated with x-ray irradiation. A biopsy revealed epidermoid carcinoma. He accordingly underwent a course of external irradiation. The lesion did not totally disappear, and several more heavy courses of external x-ray irradiation were administered to the area, each time for recurrent carcinoma.

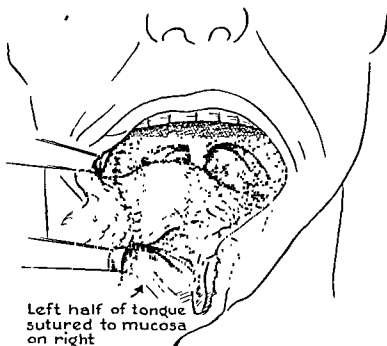


Fig 480.—The lower edge of the buccal mucosa is sutured to the cut surface of the tongue. The vermillion border of the lip and chin flap are reconstructed at the midline.

The tolerance for further irradiation to the tissue was reached. The skin over the left side of the face became red, tight and tender. There subsequently developed a radionecrosis of the mandible, which was bared intraorally over a distance of 3 cm. showing an osteolytic destruction mixed with necrotic and infected tissue.

patient soon became addicted to opiates and at the time of our first examination required 8 to 10 grains of morphine daily for the relief of pain. Further thought of therapy had been surrendered and he had been given up as a hopeless and advanced case of carcinoma. Needless to state, he presented himself in a pathetic state of defeat, malnutrition and weight loss.

Intraorally there was an ulcerating tumor involving the greater part of the left

mandible and gingival gutter. A further search for metastases was negative. After five days of preparation, the patient was submitted to a combined excision in continuity of the left floor of the mouth, mandible and radical neck dissection. The oral mucosa was closed primarily except for the most posterior part which could not be approximated because of a large defect caused from an encountered abscess. An oral fistula persisted for six weeks. The patient is now well and clinically free of disease thirty months following his operation (Fig. 491).



Fig. 491 (Case H).—A, Lateral view. The patient has had a "combined excision" with removal of the mandible. B, Front view.

This case illustrates the application of the combined excision of primary or recurrent intraoral tumors in a case that had been considered hopeless and beyond consideration of further treatment.

Intraoral Cancers Other than Squamous Cell Type.—The foregoing discussion has been entirely related to the problems of surgical management of squamous cell carcinoma of the mouth, the most common malignant tumor arising in this area. There are other tumors, however, which occur here whose treatment is surgical. It is not the intention of this discussion to cover all tumors of the mouth, but to outline the salient features of those in which surgical advances have been made.

The small mucous glands lining the buccal mucosa, particularly prominent in the palatal area, produce specific tumors which mimic exactly the tumors from the major salivary glands. The "mixed tumors," and adenoid-cystic carcinomas, or cylindromas, from these minor salivary glands are surgical rather than radiation problems, exactly as are their counterparts from the major salivary glands. Their invasive and malignant potential is not generally appreciated, however. Recently, Foote and Stewart⁷ have defined a new neoplastic entity from this group

of salivary gland tumors which may help explain some of the discrepancies in results from treatment of the intraoral salivary gland tumors. They have described the "muco-epidermoid" tumor of salivary gland origin which is a much more aggressive lesion than the ordinary "mixed tumors," but which resembles them closely superficially. They actually behave more like the adenoid-cystic carcinomas, a well known entity, and are as radioresistant. They require equally radical surgery.

CASE III.—The patient is a 26 year old white female who observed a slightly raised area measuring 1 by 2 cm. on the oral surface of the left hard palate at the age of 17. This was clinically diagnosed as a hemangioma and was treated with two applications of radium of 150 r each. The lesion subsequently disappeared.



Fig 482 (Case III).—Front view of patient six days postoperatively. She has had a wide resection of the maxilla. Weber-Ferguson incision.

However, nine years later the previously treated area insidiously began to enlarge into a prominent mass, accompanied by frequent hemorrhages. There was also bleeding from the left nostril. An x-ray examination at this time revealed a clouding and expansion of the left antrum with thinning of the medial wall.

A Caldwell-Luc exploration of the antrum was performed April 15, 1943. This was followed three years later by a resection of the hard palate. The next three years were marked by frequent hemorrhages from the operative site. Areas of recurrences were repeatedly electrically coagulated. During the course of treatment varying histologic interpretations of the tumor were made, namely, epidermoid carcinoma, adamantinoma, transitional cell carcinoma, mixed tumor and malignant tumor—type unclassified.

February 26, 1949, the patient was admitted to the Presbyterian Hospital. Examination disclosed an irregular reddish gray swelling projecting into the antrotomy from the lateral wall of the antrum. A biopsy showed the tumor to be a muco-epidermoid carcinoma of salivary gland origin. Employing a Weber-Ferguson incision, the maxilla was exposed and a wide resection performed. A moder-

ate amount of hemorrhage was encountered but controlled with a gelfoam pressure pack about an inlying intratracheal tube which was left in place for eighteen hours. Recovery was uneventful and the patient was discharged on the twelfth postoperative day (See Fig 7).

This case illustrates the futility of temporizing or minor surgical excisions in tumors of this type of the palate or antrum. The use of x-ray or coagulation is mentioned only to be condemned. Although a wide resection of the maxilla was performed, her prognosis is guarded because of the long history of the tumor and the extent of local invasion. These tumors metastasize both to regional nodes and distantly through the venous system but usually kill by local extension and destruction. It is felt that the principle of radical or wide resection of the maxilla for tumors in this area must be applied to early lesions if a respectable salvage rate is to be achieved.

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THE PRESENT STATUS OF THE TREATMENT OF HYPERTHYROIDISM

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The present day lack of agreement regarding the best form of treatment for hyperthyroidism is due to the fact that each of the various effective methods available have significant disadvantages. The ideal approach to the problem at this time must include a knowledge of the limitations of these methods so that one may apply one or more of them to each individual case to the greatest advantage. The introduction of antithyroid drugs and radioactive iodine into the field of thyroid study has introduced a changing picture into the management of hyperthyroidism which cannot receive final evaluation for many years. It is the purpose of this paper to review the present treatment of hyperthyroidism in the light of current knowledge without prejudice to the ultimate place of medical and surgical management of this disease.

SURGICAL MEASURES

The surgical treatment of hyperthyroidism, whether associated with a diffuse goiter of Graves' disease or an adenomatous goiter, has for many years revolved about one principle, the surgical removal of a sufficient mass of thyroid tissue to bring the total force of thyroid activity into normal range. In adenomatous goiter this approach produces an effect which in most cases may be considered a cure. Recurrences following this procedure in adenomatous goiter are rare. In Graves' disease the fundamental nature of the condition is of course unknown, and hyperthyroidism is only one part of the syndrome. The hyperthyroidism in itself is usually controlled by removing the major portion of thyroid tissue. Standardization of the surgical technic in the management of hyperthyroidism, and the preoperative use of large doses of iodine in thyroid surgery have led to universally good clinical results, with low mortality and morbidity rates.

In appraising the surgical treatment of hyperthyroidism, it must be realized that this form of therapy requires hospitalization, that there is a 2 per cent recurrence rate, some morbidity including such conditions as injury to recurrent laryngeal nerves and occasional transient or chronic tetany, that there is some transient hypothyroidism and even true myxedema, and that as with any other major surgery an operative mortality rate can be expected. It must be re-emphasized, however, that the mortality from competently performed thyroid surgery is now extremely low, thanks in no small part to the fact that elderly patients,

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those who are recognized as being had operative risks and those with recurrent hyperthyroidism, can now be handled satisfactorily by other nonsurgical means

ANTITHYROID DRUGS

Thiouracil.—The introduction of antithyroid drugs into the management of hyperthyroidism has created a changing picture from both medical and operative viewpoints. Thiouracil was the first of a number of antithyroid drugs to be used extensively in the treatment of hyperthyroidism. Before it was placed on the open market thiouracil had been used in the treatment of more than 5000 patients, and had been abundantly proved to be an effective means of controlling any type of hyperthyroidism with the possible exception of thyroid crisis in which its action was shown to be too slow and in the hypermetabolism of acromegaly where it appears also to be less effective.

The rate of response to thiouracil is not easily predicted. A fall in basal metabolic rate of 1 per cent per day is seldom exceeded. At the end of a few days some patients fail to show any response of consequence for the next five months, but later are well controlled. In general, hyperthyroidism associated with small diffuse goiters responds more quickly, and that associated with large nodular goiters more slowly. The production of large doses of iodine preceding thiouracil therapy is frequently helpful in obtaining prompt response. At present, its use in the treatment of hyperthyroidism has been abandoned largely because it has been shown to possess no advantages over other less toxic antithyroid drugs.

The main advantage of thiouracil is its toxic effects, such as fever, rash, or nausea, occurring in 10 to 15 per cent of all patients. These reactions usually preclude its continued use. Much more serious is the agranulocytosis which has been seen in 2 to 3 per cent. Death from this occurs in 0.5 to 1 per cent. Although the effectiveness of this drug is high, the mortality rate from thiouracil is comparable to that of thyroidectomy and therefore did not replace thyroidectomy in the routine management of hyperthyroidism. Thiobarbital, which is a much more potent antithyroid drug, was also shown to be too toxic. Astwood and Vander Laan¹ refer to patients who had previously exhibited intolerance to thiouracil and to thiobarbital. Five patients were given propyl thiouracil after they had experienced severe febrile reactions to one or the other of these two drugs. In none of these were untoward reactions observed from propyl thiouracil. This experience compares favorably with our own. Williams² reported a remission rate of 50 per cent in 100 cases of hyperthyroidism treated with thiouracil. It is possible that the general tendency toward early withdrawal of the drug because of the risk of toxic effects may have reduced the number of permanent recurrences in this group.

One of the chief advantages of thiouracil was the production of com-

plete control of the hyperthyroidism without loss of time from work. The complications of hyperthyroidism behaved similarly to their behavior following thyroidectomy.

Since thiouracil was no safer than surgery in uncomplicated moderate hyperthyroidism, and did not induce remissions as often as thyroidectomy, its greatest benefit was in the reduction of surgical risks in bad risk patients. When used (1) in severely toxic patients, (2) those with cardiac failure, (3) those who were weak from long-standing disease, or (4) in those of advanced age, many became good operative risks. In those who remained poor risks, continued therapy was recommended. By so limiting the use of thiouracil the mortality attending thyroid surgery was reduced almost to the vanishing point, but the mortality rate of the drug itself remained unchanged.

It was evident from experience with thiouracil that a safer drug was needed, and a number of other derivatives of thiouracil have supplied this need. The first clinical trials were made with *ethylthiouracil*. Fourteen patients received doses from 20 to 100 mg. daily. This limited trial revealed a high degree of activity, but its further use was abandoned because it proved to be a rather difficult substance to synthesize, and animal tests revealed the propyl derivative to be somewhat superior in terms of antithyroid potency and prolongation of action from a single dose. *Isopropylthiouracil* was tried for a limited time as well, but had properties similar to the ethyl derivative. Little need be said concerning *para-aminobenzoic acid* which is a weak antithyroid drug possessing distinct toxic propensities.

Propylthiouracil.—Subsequent clinical trial with 6-N-propylthiouracil and methylthiouracil have shown these two derivatives of thiouracil to be potent antithyroid drugs with decidedly less toxic effects than observed from thiouracil, and have largely supplanted it. Astwood¹ in the first 100 cases treated with the propyl derivative reported, found four instances of transient pruritis, two of transient headache and one of transient arthralgia. One of his patients died during therapy. This man, with advanced cirrhosis of the liver, was thought to have hyperthyroidism as well, and during the course of propylthiouracil administration showed progressive hepatic failure. The introduction of propylthiouracil therapy did not seem to modify the condition and he died in hepatic coma three months later. Astwood felt that his death was unrelated to the use of this drug. Among the first 218 patients treated by McCullagh, Hibbs and Schneider² manifestations which they attributed to the toxicity or sensitivity to propylthiouracil were seen in 7 patients. Three had mild symptoms and the drug could be continued. More severe toxic effects appeared in four, consisting of dermatitis, in one, numbness in another, urticaria in a third and granulocytopenia in the fourth. The incidence of toxic reactions in this series was 3.2 per cent, but serious reactions occurred in only 1 per cent. Up to the present time we have not seen any increased incidence of toxic reactions to the use of propylthiouracil.

Only 58 per cent show a complete response to 150 mg. or less per day, and only 87.4 per cent to doses of 200 mg. or less per day. Although some patients respond to smaller doses, a dose of 300 mg. or more per day has been effective in 96 per cent of the total. We have customarily used 300 mg. as the initial routine dose, since this is not more toxic than less effective dose levels.

Patients with hyperthyroidism associated with small diffuse goiters previously untreated with iodine, react the most rapidly to propylthiouracil. This type of case is among those which are likely to respond with a permanent medical cure. In some instances, however, the thyroid continues to enlarge during treatment, accompanied by rising basal

Concomitant Use of Iodine or Thyroid.—A word might be inserted here concerning the concomitant use of either iodine or thyroid with propylthiouracil. Early in the use of thiouracil, we observed failure to eliminate the thrill and bruit over the thyroid by giving desiccated thyroid in doses of 2 grams per day in three patients. Iodine in doses of 10 mg. per day did so in less than one week. Such small doses of iodine did not interfere with the antithyroid effect obtained from propylthiouracil. There was no significant difference in the rate of fall in basal metabolic rates in one group of patients receiving from 10 to 30 mg. of iodine per day, concurrently with propylthiouracil, as compared to a group receiving propylthiouracil alone. Up to the present time there has been insufficient experience with the use of large doses of iodine given in conjunction with antithyroid drugs. Large doses might slow the desired antithyroid effects. Thus iodine is to be used to prevent or abolish the thrill and bruit which appears in many of these glands, the dosage employed for the present ought to be small. Astwood, however, warns that the use of small doses of iodine concurrently may lessen the number of lasting remissions following the use of antithyroid drugs. One of us has recently seen two patients managed with propylthiouracil without iodine who had no evidence of hyperthyroidism eighteen months after cessation of the drug.

There is still no general agreement as to the most desirable procedure to follow once the hyperthyroidism has been initially controlled with propylthiouracil. It seems likely that inadequate dosage with only partial control of the hyperthyroidism would lead to poor ultimate results. In addition, it is well not to reduce the dose too soon, but the maximum tolerated dose should be maintained as long as is possible, rather than reduced as quickly as possible. It has been our practice

to maintain the initial dose and to administer thyroid when signs of hypothyroidism or myxedema appear, hoping thereby to increase the number of lasting remissions.

Methylthiouracil.—Methylthiouracil has also proved to be highly effective in the control of hyperthyroidism. Many accounts of its use have been published in Denmark, Sweden, England, Australia and the United States. The studies of Meulengracht and his associates,^{4, 5} Magnusson and Sorensen,⁶ and Frish⁷ include the largest series of cases studied in the earlier period.

At first, the drug was considered to have a higher degree of toxicity than propylthiouracil, but the amounts used were in excess of 600 mg. per day. This amount was soon found to be excessive. The Danish indicated that the drug retained its high efficiency at a dosage comparable to propylthiouracil. Actually, it was suggested that a dose of methylthiouracil might be found which would be similar to the effective dose of propylthiouracil and at the same time be more rapid in controlling hyperthyroidism. Kjerulf-Jensen and Meulengracht⁸ conclude that methylthiouracil is somewhat more effective than propylthiouracil in controlling hyperthyroidism, and when used in comparable doses shows no greater toxicity. McCullagh and Sirridge⁹ treated 100 patients with hyperthyroidism for from one to sixteen months, using 200 to 400 mg. per day. In cases of diffuse goiter, the mean fall in basal metabolic rate in percentage per week, using 200 mg. of methylthiouracil per day, was 4.5, as compared to 4.1 in comparable doses of propylthiouracil. Using 300 mg. per day the mean fall of basal metabolic rate in percentage per week was 6.1, as compared to 3.6 in propylthiouracil treated cases. They pointed out that the difference is not great, however, and that a wide variation in response is present. Toxic effects were recognized in only five patients in this series; four of these were mild, and did not require interruption in treatment. One patient with a history of purpura developed a recurrence of purpura while taking methylthiouracil, but the relationship of the purpura to the drug was not clear.

Astwood* regards methylthiouracil to be more effective than propylthiouracil in comparable range of dose. He considers 300 mg. of propylthiouracil to be effective in controlling hyperthyroidism in 96 per cent of cases, whereas methylthiouracil is almost 100 per cent effective in a similar dosage.

Meulengracht and Kjerulf-Jensen⁸ reported follow-up observations in 111 patients treated for one year. The doses employed were 250 mg. three times daily for the first two to three months, 250 mg. once or twice daily during the succeeding few months, with a maintenance dose of 125 mg. during the remainder of treatment. At this range of dosage, toxic reactions were encountered in 7.8 per cent of cases, in comparison to 1 per cent in the smaller dose ranges employed by other investigators. Nine per cent of the individuals treated showed genuine

* Personal communication.

relapse, making the remission rate three months after the discontinuance of the drug approximately 91 per cent.

At the present time it is not possible to conclude the ultimate remission rate in the management of hyperthyroidism by antithyroid drugs because there has not been sufficient time in follow-up. It has been suggested that the ultimate remission rate may well depend upon the care exercised in the control of the hyperthyroidism during treatment, and Astwood feels that in better controlled cases this may reach as high as 90 per cent. We have not been thus fortunate despite continued effort to control the hyperthyroidism completely or in those in whom

Our remission rate

3.—The changes in the thyroid following the use of antithyroid drugs in Graves' disease have been studied extensively. Rawson and his associates¹⁰ demonstrated an increasing hyperplasia of the thyroid with loss of colloid and increase in vascularity in all cases, comparable to the changes observed in the thyroid of rats treated with thiourea. DeRobertis¹¹ showed that these goitrogens worked by interference with enzyme systems within the thyroid involved in the synthesis of organic thyroid fraction from stored inorganic iodine. Under antithyroid agents there is a marked decrease in organic iodine within the gland owing to suppression of the hormone containing organic iodine. Iodine is absorbed but not utilized. The interruption in thyroxine synthesis is believed to stimulate thyrotropic activity in the pituitary, which in turn causes further hyperplasia of the thyroid. This induced hyperplasia can be prevented in the experimental animal by hypophysectomy.

The hypertrophy and hyperplasia of the gland at times is very appreciable indeed. Rarely, however, does it lead to sufficient compression of the trachea to be an indication for thyroidectomy. The enlargement usually persists during the period of this treatment. At times this enlargement is of sufficient cosmetic importance to the patient to make thyroidectomy the choice. Once treatment has been discontinued the thyroid may return to its pretreatment size. Meulengracht and Kjerulf-Jensen⁸ stated that 50 per cent of their patients had no goiter at the end of treatment, 30 per cent of these had never shown enlargement during therapy; 20 per cent had lost whatever enlargement had appeared during treatment. Among the 50 per cent showing an enlargement of the thyroid at the end of treatment, there had been a reduction in size in 25 per cent, and no change in the remainder. In general, it has been our experience that enlarging glands during treatment persist when the drug is discontinued. We have not seen impressive remissions in this group of cases and feel for this reason that glands showing tendency to enlarge during therapy are not likely to be cured by antithyroid drugs.

Significant Problems Relating to Use of Antithyroid Drugs.—A number of highly significant problems relating to the employment of antithyroid drugs in the management of hyperthyroidism remain to be

settled. Thyroidectomy, after proper control of hyperthyroidism, results in permanent and complete return to health in about 90 per cent of cases, and tends to shorten the time of this recovery. In contrast, prolonged drug therapy is at times difficult, due to poor cooperation of the patient; when improvement appears treatment may be allowed to lapse. Some will sooner or later prefer to have their problem settled by thyroidectomy. Unless antithyroid drugs can duplicate surgical results, they will not replace surgery in the management of the uncomplicated hyperthyroidism of Graves' disease. At the present time, hope for this is distinctly less than a few years ago.

In the management of recurrent hyperthyroidism, however, where an increased risk to the recurrent laryngeal nerves, or the parathyroids is significant, their use seems more clearly indicated. Complete control of the disease with propyl or methyl thiouracil is usually advised in all patients with severe hyperthyroidism, in all those over 45 years of age, as well as in those with complicating factors, such as poor cardiac status. Once the disease is completely controlled Lugol's solution is given prior to operation, and the antithyroid drug is discontinued. It has been our impression that Lugol's solution must be given for from four to six weeks in order to reduce the vascularity and the friability of the gland to a minimum at the time of operation. The patient may be ready for surgery sooner but the "gland is not." In patients whose hyperthyroidism is complicated by extreme old age, by cardiac or other disorders which will prevent them ever from becoming good surgical risks—even after the elimination of hyperthyroidism—propylthiouracil or methylthiouracil may have to be continued indefinitely.

There remains another group of unsettled questions in relationship to the use of antithyroid drugs in the management of hyperthyroidism. Whether significant histopathologic change will follow the prolonged use of antithyroid drugs is still not established. Bartels¹² reviewed 1200 goiters to show malignant change. Three of them were in adenomatous goiters and four in diffuse goiters. He pointed out that this incidence must be compared with that before using antithyroid drugs, before its true significance can be determined. Other questions to be settled concerning the medical management of diffuse goiter relate to the frequency with which the remission rate can be increased by the type of associated therapy in conjunction with the antithyroid drug employed. If the remission rate can be shown to be greater when iodine is withheld, this fact will outweigh the importance of eliminating the thrill and bruit induced during therapy. Similarly, if more lasting remissions can be produced in patients by inducing hypothyroidism (and requiring thyroid extract) this procedure would be preferable to dosages only large enough to produce euthyroidism.

RADIOACTIVE IODINE

Radioactive iodine is the latest therapeutic tool introduced for the treatment of hyperthyroidism. Like surgery and antithyroid drugs,

radioactive iodine also has advantages and disadvantages. Its ultimate place in the treatment of goiter cannot be accurately established for many years. It is now seven years since Hamilton and Lawrence¹⁴ and Hertz and Roberts¹⁵ reported on the treatment of hyperthyroidism with radioactive iodine. The experiences of a great many investigators, including Soley,¹⁶ Hertz and Roberts,¹⁵ Chapman and Evans,¹⁷ Haines et al.¹⁸ and Crile et al.¹⁹ have established the effectiveness of radioactive iodine in the immediate control of hyperthyroidism. All subsequent studies have continued to confirm this and some patients now have been in remission for several years.

In the earlier years a mixture of about 90 per cent I^{130} and about 10 per cent I^{131} was employed. Since the release of I^{131} by the Atomic Energy Commission two years ago this isotope has received extensive consideration in the management of hyperthyroidism. A number of properties of I^{131} make it an attractive isotope for clinical use. It differs from many radioactive substances in that its half life is only eight days. This property is considered to minimize the later ill effects due to retention of a long-lived radioactive substance within the body. Furthermore, its safety is increased because of the fact that its radiation is largely in the form of beta rays which do not penetrate tissues for more than 1 or 2 mm. Since it is concentrated in the thyroid, it does not cause demonstrable damage to tissues immediately outside of the thyroid. Gorbman,²⁰ however, has given young mice massive doses of I^{131} and produced complete destruction of the thyroid, loss of the parathyroids, lesions in the tracheal epithelium, and in the recurrent laryngeal nerve. Up to now no comparable changes have been demonstrated in patients and damage has not been reported to the kidneys, bone marrow, testes or other organs.

Furthermore, the chemical and physiologic behavior of radioactive iodine is identical to that of ordinary iodine and the thyroid handles it in the same way that it does stable iodine. In hyperthyroidism the uptake and concentration of I^{131} within the thyroid is much greater than in the normal thyroid. Hamilton²¹ estimates a concentration in the thyroid in an amount 10,000 times greater than in the blood or in any other organ. The isotope is stored within the thyroid until it has lost the major part of its radioactivity, after which most of it is excreted by the kidneys as ordinary iodine. For these reasons the amount of irradiation received by the thyroid after an average dose of radioactive iodine is much greater than the amount of irradiation which can be delivered by roentgen therapy without damage to the skin. The average dose of 4 mc. by Oak Ridge standard, given to a patient with Graves' disease and a goiter weighing 50 gm. which takes up 50 per cent of the administered dose, delivers the equivalent of 4000 r to the thyroid.

I^{131} is in the form of sodium iodide and is dissolved in water. It is

I^{131} is in the form of sodium iodide and is dissolved in water. It is

from the ordinary dose, but irradiation sickness has occurred when large doses are used, such as in the treatment of cancer of the thyroid. Among the disadvantages, one of the most immediate relates to technical difficulties in distribution and handling. A more important consideration in the use of radioactive iodine is its possible ultimate carcinogenic properties. Although there is little experimental or clinical evidence to suggest that intensive irradiation of this nature will be carcinogenic, this possibility demands careful consideration. Whether the incidence of carcinoma of the thyroid will be significantly altered by its use remains to be demonstrated, but most authorities feel that it is not likely to increase its incidence. None the less, radioactive iodine is largely being reserved for use in older patients with hyperthyroidism, or for patients with short life expectancies. It is also being used where serious heart disease, or other complications, might add considerably to the risk of surgical treatment, and for patients with recurrent hyperthyroidism, in whom one or more previous resections of the thyroid have been performed, where unilateral paralysis of the vocal cords, or extremely small amounts of thyroid remain from previous operative procedures.

The matter of dosage to be employed is one of the major problems confronting investigators in this field. Up to the present time there have not been any uniformly satisfactory methods of estimating the amount of radioactive iodine to be given in one dose to effect a cure. Clinical estimates of the size of the gland are no consistent criterion to dosage partly because of the inaccuracy of proper estimates, but more particularly because of the great variability in the response of different thyroid glands to the same dosage. We have attempted to adopt the policy that for the treatment of Graves' disease the initial dose should be one-half to two-thirds of the average dose required to effect a cure. When 4 mc. are given, about one-half of the patients are well after a single treatment, and only 10 per cent develop transient hypothyroidism. The size of the second dose has been gauged on the response of the hyperthyroidism to the first. If the basal metabolic rate is unchanged after two months, the second dose may be doubled. If the basal metabolic rate has fallen half-way to normal, the first dose may be repeated. If the basal metabolic rate has dropped two-thirds of the way to normal, one-half of the original dose is usually given. If there is only slight residual hyperthyroidism, or if the basal metabolic rate is at the upper limit of normal, no further treatment is given, because maximum effects of a single dose sometimes are not apparent for three or four months.

In Graves' disease, our average initial dose has been 4 mc., unless the thyroid is unusually large and the hyperthyroidism severe, in which case 6 or even 8 mc. have been given. Our experience has indicated that the dose required to control hyperthyroidism of Graves' disease is dependent more upon severity than upon the size of the gland, although individual variability must be recognized. Crile and his associates¹⁹ have demonstrated that in nodular goiter with hyperthyroidism the

average initial dose should be distinctly increased over that of diffuse goiter. In these 8 to 15 mc., depending upon the size of the gland, have been employed

are highly satisf

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reduces in size,

Nodular goiters usually shrink but do not disappear. Auricular fibrillation tends to revert to normal sinus rhythm just as after thyroidectomy.

Recently Kelsey, Haines and Keating²² have published a review of the present status of radioactive iodine in the treatment of thyroid disease. The addition of the series reported by Crile's group to the series reviewed by these authors brings the total cases to 446. Undoubtedly many others have not been included in this study. However, 51 per cent of the 446 cases were euthyroid after one dose of I^{131} , while hypothyroidism occurred in only 4.2 per cent. Some of these were transient. Williams and his co-workers²³ mention the occasional accentuation of hyperthyroidism after the first dose. We have recently seen several instances of this type. Exophthalmos behaves in general in the same way that it does following thyroidectomy or antithyroid drugs. Soley and Miller²⁴ mention an increase in exophthalmos in six out of twenty-six so studied.

Collected observations show a uniform fall in basal metabolic rate, a fall in protein bound iodine, and a rise in blood lipids. Transient fever, rise in sedimentation rate, and tenderness of the thyroid area have also been observed. Transient leukopenia was seen in one instance, but agranulocytosis has not been observed. There have been no recurrences seen in those cases in whom euthyroidism has occurred.

It is to be predicted that radioactive iodine will reduce many of the present indications for propylthiouracil and methylthiouracil. It is likely that it is the treatment of choice when hyperthyroidism is present in the bad risk patient, or attended by complications such as recurrent hyperthyroidism, or vocal cord paralysis, because it is likely to produce a more lasting remission than antithyroid agents have been shown to do. It is likely that it will never be the routine treatment for nodular goiter with hyperthyroidism because surgery usually cures the disease permanently and tentative observations show a less satisfactory response to I^{131} . Many years of observation will be required to determine whether or not it will be the ultimate method of treatment for young patients with Graves' disease. Since apparently no complications, apart from hypothyroidism, attend the use of radioactive iodine, it is probably the most promising treatment of hyperthyroidism of the future.

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RADICAL OPERATION AND PALLIATIVE THERAPY FOR CARCINOMA OF THE BREAST

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THE RADICAL OPERATION

What is the standard radical operation for carcinoma of the breast? After a review of the literature on the treatment of breast cancer a detailed answer to this question is not found. Brooks and Daniel¹ have made the statement that "there is no such thing as a radical operation for carcinoma of the breast as there is a Billroth 11 for carcinoma of the stomach," and "even Halsted^{2, 3, 4, 5, 6, 7} was somewhat confused as to what constituted the operation bearing his name." At one time Halsted did not remove all of the pectoralis minor muscle, at another he removed the supraclavicular nodes, and still later removed a part of the chest wall. In 1907 he advised stripping the fascia from the upper part of the rectus abdominis, the serratus anterior and the subscapularis muscles, and at times from the latissimus dorsi and the teres major muscles. He speculated that removal of the shoulder and even amputation at the hip might eradicate metastases to bone. In 1913 Halsted stated that he had discontinued the incision out on the arm and advised a vertical incision extending upward toward the clavicle.

In the development of the radical operation for carcinoma of the breast Halsted tried many methods which might seem somewhat confusing when his reports are read. It is surprising that there has been so little change in the fundamental concept of the operation in fifty-five years. We might with justice speak of the Halsted principle of the radical operation, rather than the Halsted operation.

Although the technic of the radical breast operation as used by surgeons in general may vary widely, the fundamental principles enunciated by Halsted and Willy Meyer⁸ are still sound. These principles are; (1) excision of a large area of skin over the breast; (2) excision of both pectoral muscles; (3) complete axillary dissection beginning at the apex; and (4) removal of all tissues excised in one mass.

As far as the details of radical mastectomy are concerned, I agree with Brooks and Daniel that there is no standard operation for carcinoma of the breast. There is disagreement among surgeons concerning the type of skin incision, the extent of skin removal with plastic or skin graft closure of the wound, the removal of the clavicular portion of the pectoralis major, the removal of the rectus muscle fascia, the thickness

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muscle and the chest wall. The pectoralis muscle is removed except the long thoracic

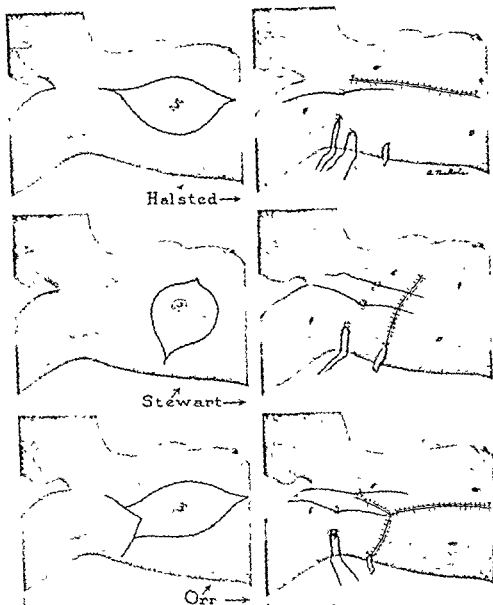


Fig. 483.—The three skin incisions shown for carcinoma of the breast. Closures of stab wounds near peripheries of flaps and skin and intercostal muscles to obliterate space in axilla are shown (right). The ends of the sutures are left long for fixation of marine sponge dressings.

and thoracodorsal nerves. If lymph nodes are found near the latter nerve it is sacrificed. The intercostohumeral nerve is removed.

After the axilla is cleanly dissected free of all fat and areolar tissue the remaining attachments of the pectoralis muscles are divided at their

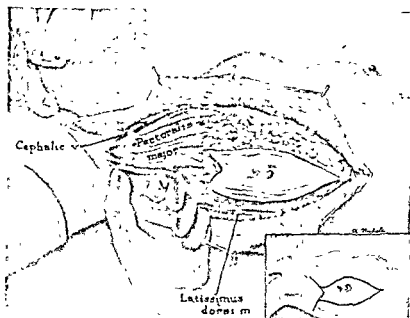


Fig. 484.—Inset shows type of skin incision. Flaps have been dissected with minimum of attached fat. Dissection extends medially to midline, laterally to just beyond the anterior border of the latissimus dorsi muscle, above to expose the upper border of the pectoralis major muscle along the clavicle and insertion of this muscle to the arm, and below to the costal margin. Line of incision shown through pectoralis major near its attachment to the clavicle.

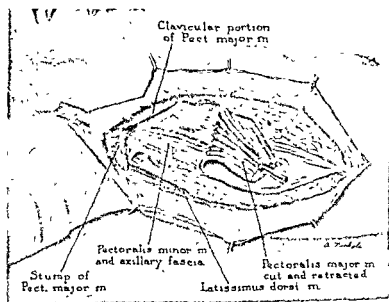


Fig. 485.—The pectoralis major muscle has been divided near its insertion and retracted downward to expose the axillary fascia and pectoralis minor muscle.

origins and removed with all fat and fascia down to the ribs, including the fascia over the thoracic attachments of the rectus muscle. All structures dissected free are removed in one mass.

Meticulous hemostasis is necessary to promote satisfactory wound healing. After the dissection has been completed the entire wound is thoroughly washed with physiologic sodium chloride solution. The wound is finally carefully inspected and all remaining bleeding vessels are ligated (See Fig. 486.)

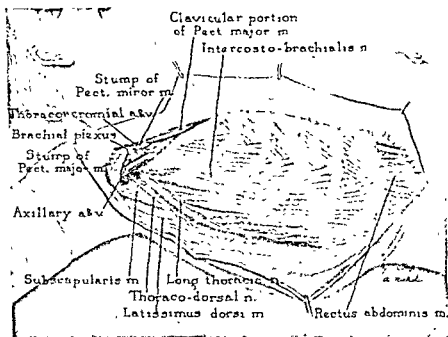


Fig 486.—Mass dissection completed

Mattress sutures (usually three) are placed through the axillary flap and intercostal muscles so that when tied they will fold the axillary skin high in the axilla to cover the axillary vessels and chest wall with a minimum of remaining dead space. The skin margins are carefully approximated and closed with cotton or silk. If a large area of skin has been removed, which prevents closure of the wound, the margins of the remaining skin flaps are sutured to the underlying muscles and a split skin graft cut from the thigh with a dermatome is sutured into the defect. To avoid accumulation of serum beneath the skin flaps, puncture wounds are made at three or four points near the attachments of the flaps to afford drainage. A drain is passed into the axilla through the lateral end of the incision or through the lateral skin flap. The ends of the mattress sutures, which have been left long, are tied over a marine sponge fitted into the axillary sulcus (Fig. 487). The remainder of the area of skin flaps is covered with moist gauze and additional marine sponges are applied.

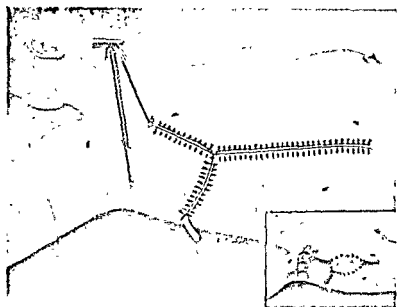


Fig 487.—Wound closed. Locations of stab wounds in skin flaps are shown

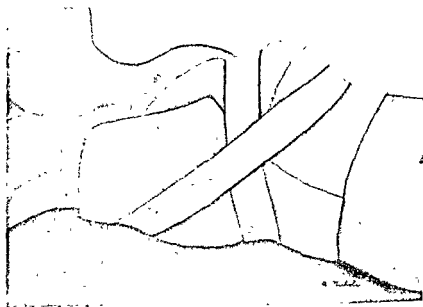


Fig 488.—Dressing applied and held firmly in position with strips of elastoplast.

Gauze dressings are laid over the sponges and the entire dressing mass is held firmly to the chest wall and axilla with strips of adhesive or elastoplast (Fig 488). Over these dressings a breast binder is applied

(Fig. 489) to aid in immobilization of dressings and skin flaps. The dressings are quickly soiled with bloody drainage and are changed within twenty-four hours after operation. The drain is removed with the first dressing. A pressure dressing is reapplied. The pressure should not be great enough to interfere with the blood supply to the skin flaps. If a skin graft is applied it is covered with zeroform gauze and the dressing is held in place with separate adhesive strips so that the remainder of the breast dressing may be changed without disturbing the skin graft dressing. The dressing on the graft is not removed for ten to twelve days.

The arm is left free and the patient is encouraged to begin arm movements after the first postoperative day.

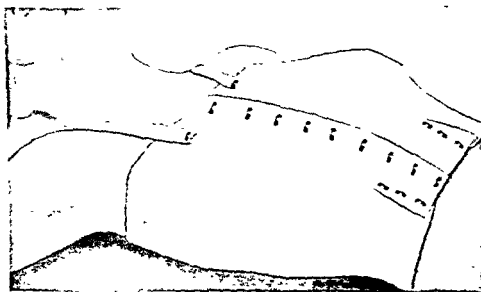


Fig. 489.—Breast binder applied over dressing.

SELECTION OF PATIENTS FOR OPERATION

The results of operative treatment must depend, in great measure, upon the types of cases selected for the radical operation. Published results may be expected to be of but relative value until some standard of operability is generally adopted. But it may be too much to ask that all surgeons adopt such a standard. It is generally believed that operation is the only type of therapy that may cure cancer of the breast, and any patient is entitled to the benefit of the doubt. The possibility of benefit of the radical operation in individual and frequently borderline cases must, at present, depend upon the experience and judgment of the surgeon.

The estimate of operability as presented by Haagensen and Stout¹⁰ is so clear-cut that it is here reproduced.

Any patient whose general physical condition is good enough to risk major surgery should be treated by radical operation except as follows:

1. When the carcinoma is one which developed during pregnancy or lactation.
2. When extensive edema of the skin over the breast is present.
3. When satellite nodules are present in the skin over the breast.
4. When intercostal or parasternal tumor nodules are present.
5. When there is edema of the arm.
6. When proved supraclavicular metastases are present.
7. When the carcinoma is the inflammatory type.
8. When distant metastases are demonstrated.
9. When any two, or more, of the following signs of locally advanced carcinoma are present:
 - (a) Ulceration of the skin.
 - (b) Edema of the skin of limited extent (less than one third of the skin over the breast involved).
 - (c) Fixation of the tumor to the chest wall.
 - (d) Axillary lymph nodes measuring 2.5 cm. or more, in transverse diameter, and proved to contain metastases by biopsy.
 - (e) Fixation of axillary lymph nodes to the skin or deep structures of the axilla, and proved to contain metastases by biopsy.

Haagensen and Stout offer very convincing evidence that these criteria should be followed by recording 109 cases treated by radical operation with but 2.8 per cent of five year survivals and no permanent cures, which did not meet their operability requirements and which they consider were unsuited for operation.

One might logically question some of the limitations of operability imposed by Haagensen and Stout. There is still difference of opinion concerning the first premise that operation is contraindicated in pregnancy and lactation. These authors classify such patients as "categorically inoperable." It is well known that such cases have a low incidence of five year survivals with operation, but since they are definitely incurable without operation, it is reasonable to hope that well selected cases may be benefited by radical operation. This is particularly true if involvement of the axillary nodes cannot be demonstrated. Harrington¹¹ has reported ninety-two carefully studied patients operated upon during lactation or pregnancy. In fourteen of these cases having no demonstrable metastases in the axilla, 61.5 per cent of the patients lived five years and 40 per cent lived ten years. Of seventy-eight patients with axillary metastases 5.7 per cent lived five years and 3.4 per cent lived ten years.

What advice should be given to a woman, who has had an operation for carcinoma, concerning future pregnancy? Harrington believes it wise to advise women not to have pregnancies after operation for breast cancer, although his reported results are satisfactory. Brooks and Proffitt¹² conclude that there is no evidence that pregnancy influences the development of mammary cancer, but pregnancy does increase the rapidity of growth of coexisting breast cancer. These authors express the belief that the advice given to a woman, who has had a breast cancer, is entirely a matter of the surgeon's judgment in the individual case.

There may also be honest disagreement with Haagensen and Stout concerning the operability of the inflammatory type of breast carcinoma. Metastases develop early in a very high percentage of such cases. Meyer¹³ and associates report sixty-one cases treated by radical mastectomy and irradiation, three of which lived more than five years after operation and one was alive more than nine years. They believe that these results justify radical operation and postoperative irradiation. If this type of carcinoma is to be treated by radical operation, cases should be selected with great care and only those patients chosen for operation who have a minimum of the inflammatory type of involvement of the breast with no clinical evidence of metastases to the axillary nodes or skin.

The radical operation is advisable in all cases falling in Steinthal's clinical classification Groups I and II. In Group I the tumor is limited to the breast and is freely movable, and the axillary nodes are not palpable. In Group II a larger part of the breast is involved, the skin is adherent, and the axillary nodes are palpable. Operation should rarely be done in those cases with evidence of carcinoma beyond the areas indicated above except in a few instances when a palliative operation may be advisable in the aged, or for patients having ulcerating lesions.

COMPLICATIONS OF THE RADICAL OPERATION

The mortality of the radical operation is low, rarely exceeding 2 per cent. *Postoperative infection* is infrequent. If infection develops in the axillary region, healing is prolonged and disability is often increased. *Delayed healing* due to necrosis of skin flaps is relatively common but rarely extensive enough to require skin grafting. *Collections of blood and serum* beneath the skin flaps may be reduced to a minimum by proper hemostasis, drainage and pressure dressings. If serum accumulates beneath the skin it may be removed by aspiration with less danger of infection than by repeated insertion of an instrument through the suture line.

Edema of the arm follows the radical breast operation in a large percentage of cases. McDonald¹⁴ says that some degree of lymphedema invariably occurs following a radical axillary dissection. The edema is often confined to the upper arm and is relatively unimportant. Extensive edema may involve the entire arm and hand and result in serious inconvenience or disability in a small percentage of cases. Extensive edema is somewhat more frequent in obese patients. The edema is due to lymph stasis which may be aggravated by infection and perhaps by irradiation therapy. Since the treatment of the edematous arm is very unsatisfactory every effort possible should be made to prevent it. By carefully covering the axillary vessels and adjacent chest wall with the axillary skin flaps, infection and scar formation are minimized.

Limitation of motion at the shoulder due to contractures is reduced or completely prevented by selecting suitable skin incisions and by early motion and use of the arm.

The healed skin flaps are frequently *hyperesthetic* and cause discomfort and worry. When the patient is assured that the disturbed sensation is not due to recurrence of the cancer, the discomfort is usually well tolerated.

CONTROVERSIAL FEATURES OF THE RADICAL OPERATION

What Type of Skin Incision Should be Selected for the Radical Operation?—The skin incision should be used which is best suited to the individual case. To be committed to one type of incision is fallacious judgment. With rare exceptions the incisions here illustrated (Fig. 483) are satisfactory. An incision extending out on the arm or across the axilla should not be used. Such an incision produces scarring which may limit arm function.

How Much Skin Should Be Removed at the Radical Operation?—Should the dictates of Halsted be followed that "to attempt to close the breast wound more or less regularly by any plastic method is hazardous, and, in my opinion, to be vigorously discountenanced," or should the wound be closed without skin graft in the majority of cases? Lewis and Richhoff¹⁵ expressed the opinion "that the operator cannot be held responsible for undiscoverable metastases, either regional or remote, but should be held to account for a local recurrence." Haagensen¹⁶ believes that the surgeon may not be blamable for parasternal recurrences, but he cannot escape responsibility for the button-like recurrent skin nodules

the area of
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surgeon's
instruments as he manipulates or sutures the edges of the wound. Handley¹⁷ has stated that the practice of removing a very wide area of deep fascia and a less wide area of skin gives better results than the removal of less fascia and more skin.

It seems sensible to believe that the extent of skin removed should depend upon the character and size of the tumor, the location of the tumor, and the presence or absence of clinical evidence of axillary metastases. It is well known that local recurrences are more common when axillary metastases are present, and such a positive finding should be considered when planning the area of skin to be removed.

Thoroughness of the Axillary Dissection.—The incidence of local recurrence not only depends upon the presence of axillary metastases, but upon the number of axillary lymph nodes overlooked at operation. In a study of lymphatic spread of carcinoma of the breast Monroe¹⁸ found that the greater the number of lymph nodes removed, the greater the patient's chance of recovery. Local recurrence must then depend upon the thoroughness of the axillary dissection as well as the extent of skin removed. It is probable that axillary metastases occur in a higher percentage of cases than average records indicate. In a reexamination of the axillary nodes in thirty cases in which examination had been rou-

tinely made for metastases, Saphir and Amromin¹⁹ discovered, by making serial sections of a large number of nodes, that an additional 33 per cent contained cancer. The prognosis depends upon both the thoroughness with which the lymph nodes are removed by the surgeon and examined by the pathologist.

Late Local Recurrence.—Local recurrence may develop many years after operation. This point is well illustrated in Halsted's first fifty reported cases. Six per cent of the patients had local recurrence in 1894, and 9 per cent 4 years later. Thirty-seven years later Lewis and Rienhoff found records indicating that 31.9 per cent of Halsted's patients eventually developed local recurrence from three to twenty years after operation. The incidence as reported by Haagensen and Stout differs little in the cases grafted and those with plastic closure. These authors warn that their statistics are of little value because of the variation in the technic of operation by various surgeons. Although Conway and Neumann²⁰ report local recurrence in 21 per cent of patients with skin grafts, with 35.5 per cent of local recurrences within the grafted area, and in 6 per cent of patients with plastic wound closure, these authors recommend more radical excision of skin, particularly when the tumor is large. White²¹ has said that with either the Halsted or Handley approach, there is a high incidence of local recurrence, and that there is no proof that one method is better than the other in avoiding local recurrence. Rodman's²² remarkably low incidence of 2.2 per cent of local recurrences with the plastic closure operation described by his father, indicates that there is some doubt about the value of removing large areas of skin.

Recurrence with Skin Grafting and with Plastic Closure Compared.—The question concerning the removal of large areas of skin with skin graft closure or removal of lesser areas of skin with plastic closure cannot be decided from the evidence presented in published reports. It seems reasonable to the author that plastic closure of the skin can be made safely in the majority of cases if proper care is used in the selection of cases considered suitable for the radical operation. The care with which the skin flaps are made and the completeness of the axillary dissection are probably of more importance than the extent of skin removed.

The well known fact that following operation some patients develop extensive skin metastases and others equally extensive visceral and bone metastases lends support to the doubt that the area of skin removed with the breast is a sufficiently decisive factor to warrant removal of wide areas of skin in all cases.

Table 1 shows the incidence of local recurrence after radical mastectomy with both skin grafting and plastic closure of the wound.

How Much Subcutaneous Fat Should be Removed from the Skin Flaps?—In Halsted's original description of his technic all fat was carefully dissected from the axillary skin flap. Haagensen described the skin flaps he uses as 3 to 4 mm. thick, covered with only a delicate layer of fine fat lobules. Sugarbaker and Wiley²³ recommend that skin flaps be dissected in a graduated fashion, thin at the line of incision with a grad-

ual increase in thickness as the base is reached. A flap of graduated thickness toward its base assures a better blood supply than a very thin flap throughout its width. With a little experience flaps can easily be made leaving a minimum of fat attached.

Should the Pectoralis Major Muscle Be Removed Completely?—It is not necessary to remove the clavicular portion of the pectoralis major muscle for adequate exposure of the axilla. This is not a very vital point and may be left to the discretion of the surgeon without fear of changing the results of the operation.

Should Removal of the Anterior Sheath of the Rectus Muscle Be a Part of the Operation?—Since Handley expressed the belief that the chief lymphatic pathways were located in the fascia, routine removal of

TABLE I
LOCAL RECURRENCE FOLLOWING RADICAL MASTECTOMY AFTER A MINIMUM OF FIVE YEARS

Author	Year	Recurrence with Skin Graft		Recurrence with Plastic Closure	
		Num-ber	Per Cent	Num-ber	Per Cent
Lewis and Rienhoff ¹⁵	1932	322	30.1	116	39.7
Simmons ²³	1942			104	6.0
Haagensen and Stout ²⁴	1942	167	22.2	401	21.9
Rodman ²⁵	1943			132	2.2
White ²⁶	1946			239	22.6
Robinson ²⁸	1948			173	16.7
Conway and Neumann ²⁹	1949	188	21.0	67	6.0

the rectus fascial sheath has been considered advisable by many surgeons. In 1907 Halsted recommended stripping the sheath from the upper part of the rectus muscle. Haagensen²⁷ in 1946, stated that he does not remove the rectus fascia except in cases with the tumor situated in the lower half of the breast. It seems unnecessary to remove the rectus fascia in all cases. When the tumor is large or located in the lower half of the breast or when axillary nodes are demonstrated clinically, removal of the rectus sheath as a part of the radical operation is a logical procedure.

Should the Thoracodorsal and Long Thoracic Nerves be Sacrificed?—The anatomical location of the long thoracic nerve against the chest wall permits it to be easily stripped of all fat and fascia and it need not be sacrificed. Lymph nodes often lie in close proximity to the thoracodorsal nerve. When such nodes are demonstrable by palpation or vision during the axillary dissection the nerve should be sacrificed. The nerve should be preserved in all other cases.

Should the Axillary Vein be Resected as a Part of the Radical Operation?—One may logically question the advisability of routine removal of the axillary vein, as recommended by McDonald. Trimble²⁸ recom-

mended resection of the axillary vein if it is found invaded by metastatic growth, and observed that no harm will follow this procedure, not even postoperative edema of the arm. The recommendation of Trimble seems to answer the above question adequately.

Is Operation for Local Recurrence Ever Justifiable?—Operations for extensive local recurrences are certainly of doubtful value. X-ray therapy will produce just as good results, with less discomfort to the patient. It cannot be hoped that either treatment will effect a cure or greatly prolong life. For local recurrences which do not require extensive surgery, operation may be indicated in selected cases. Guthrie²⁹ reported a patient who lived nine years after excision of a local recurrence.

PALLIATIVE THERAPY

What Is the Value of X-ray Therapy in Carcinoma of the Breast?—Goin³⁰ expressed the opinion that "the debate is almost entirely as to the extent to which irradiation should augment or even replace surgery in the treatment of the disease, and indecision is expressed even by those of the widest experience." Pfahler and Keefer³¹ stated in 1947 that an insufficient number of cases of preoperative irradiation have been recorded to justify any final conclusions from statistics. These authors believe, however, that there is theoretical and biological evidence favoring preoperative irradiation since there is a tendency for such treatment to devitalize or destroy the more malignant types of cells. They present additional evidence that normal tissues are less receptive to implantation of cancer cells after preoperative irradiation. Their conclusion is that the operative results can be improved by preoperative and postoperative roentgen therapy, or by a combination of the two. Their collected statistics show a 10 per cent increase in five year survivals after postoperative therapy. Stenstrom and Baggenstoss³² report 110 cases with axillary metastases treated by radical mastectomy and postoperative irradiation with 41 per cent of five year survivals and 22 per cent of ten year survivals. These results are better than those of the radical operation.

In 1947 Lenz³³ expressed the opinion that there is still no agreement as to the exact value of roentgen therapy in carcinoma of the breast, either when used as the only treatment or when combined with mastectomy as pre- or postoperative therapy. Routine prophylactic roentgen therapy has been discontinued at the Presbyterian Hospital in New York and is given only when requested. Lenz remarks that constant comparisons are being made between nonirradiated series of cases and those receiving postoperative irradiation irrespective of whether the tumor dosage is a few hundred or several thousand roentgens.

McGraw's³⁴ results were inconclusive as to any clearcut beneficial influence of such treatment. Gordon-Taylor expressed himself very clearly in 1948 when he said that "save for one very brief and perhaps fortuitously unhappy period long ago, I have personally eschewed the method of postoperative radiation as a supplement to radical surgery

in the cases of mammary carcinoma which are by common usage now classified as Stage I and Stage II. For such I have preferred a sharp knife, a stout heart, and unquenchable optimism, and have regarded the widest radical surgery untrammelled by ancillary radiation as the method of election in almost every case belonging to these two categories." Gordon-Taylor's results seem to support his positive assertion (Table 2).

As an example of the widely divergent opinions concerning the best treatment of carcinoma of the breast, the recommendation of McWhirter²⁵ of the Royal Infirmary of Edinburgh is noteworthy. This author advises a simple mastectomy and postoperative irradiation of the axilla as a method of treatment superior to radical mastectomy. He

TABLE 2
RESULTS OF RADICAL OPERATION FOR CARCINOMA OF THE BREAST

Author	Year	Group I Without Axillary Metastases			Group II With Axillary Metastases		
		No.	5 Year Surv- ivals, per cent	10 Year Surv- ivals, per cent	No.	5 Year Surv- ivals, per cent	10 Year Surv- ivals, per cent
Sistrunk and MacCarthy ²¹	1922	86	65.1		132	21.9	
Brooks and Daniel ¹	1910	12	91.6		60	26.7	
Haangenson and Stout ²⁴	1912	237	61.2		385	21.0	
Simmons ²²	1912	42	73.0	70.0	99	30.0	18.0
Guthrie ²³	1913		65.5	40.9		23.0	9.8
Harrington ²⁶	1916	2127	75.7	57.9	3728	30.4	16.4
McGraw ²⁷	1917	161	61.0		251	29.6	
Robinson ²⁸	1918	63	69.9		74	24.3	
Gordon-Taylor ²	1918	113		81.0	201		29.4

emphasizes the point that if this type of treatment is to be successful, a high standard of radiotherapy is essential. He reports a five year survival rate of 56 per cent in all "operable" cases. McWhirter quotes results of other surgeons using the radical operation and concludes that his results "will bear comparison with any other published figures" and give support to the view that the hypothesis underlying the method of treatment is sound. In discussing local mastectomy Cade²⁹ remarks that as a clinician he is not attracted by the idea of removing part only of a cancer, be it in the breast or elsewhere, if he can with impunity to the patient, remove all of it. As a routine surgical procedure, regardless of the stage of the disease or age of the patient, Cade regards the method of staged mastectomy as a step and quite unwarrantable. One may very logically conclude that the method of staged mastectomy is a method which cannot cure

I personally believe that a large majority of surgeons would prefer to accept the McWhirter method of treatment as merely a hypothesis until more convincing evidence of its value is forthcoming.

Opinions for and against irradiation therapy have been strongly expressed by able roentgenologists and surgeons. These same roentgenologists and surgeons generally agree that inoperable cases should be treated by irradiation and recognize that palliation received by such treatment is usually beneficial and often amazingly efficient. If good results are achieved in the inoperable cases there appears to be some inconsistency in the reasoning that irradiation will not benefit the patient after operation if tumor cells are left in tissue within or beyond the field of radical mastectomy. This inconsistency becomes more apparent when one considers that cells spreading beyond the operative field may be rapidly growing and anaplastic, and therefore, more radiosensitive. It is our present practice at the University of Kansas Medical Center to advise postoperative irradiation when axillary metastases are reported by the pathologist. Although positive statistical proof of benefit may be lacking, the knowledge that cancer cells are destroyed or devitalized by irradiation justifies such treatment.

It is obvious from the above discussion that the value of preoperative and postoperative irradiation cannot, at present, be estimated with assurance. This situation exists because there has been such a great variation in the treatment given. Until studies of a large series of selected similar cases are recorded, which have been treated by standardized methods, no reasonable estimate of the value of roentgen therapy can be made.

What Is the Value of Hormonal Therapy?—The use of hormones never cures a patient of carcinoma of the breast but there is unquestionable evidence that certain hormones are of value as palliative therapy. Adair⁴⁰ has used testosterone propionate in a dosage of 100 mg. three times per week for ten weeks, or a total of 3000 mg. This treatment was followed by a maintenance oral dose of 40 to 60 mg. of methyl testosterone daily for eight weeks. This had no effect in some cases but in others palliation was obtained for more than two years. Adair states that the maximum dosage has not been established. The best results were obtained in patients having bone metastases. These patients were relieved of pain, gained weight, were able to sleep without narcotics, appetite was improved and they developed a feeling of well-being. Bed-fast patients occasionally were able to return to their occupations. The disagreeable features of testosterone therapy are hirsutism, voice changes, acne, enlargement of the clitoris, and increase in libido. The experience of Taylor and associates⁴¹ with the use of androgens was similar to that of Adair.

Hermann and co-workers⁴² used a synthetic estrogenic hormone (ethinyl estradiol) administered orally. The dosage was 0.15 to 0.7 mg. daily. There was some clinical improvement in superficial and pulmonary lesions in 40 per cent of patients over 60 years of age. The bad effects

MODERN TECHNICS IN GASTRIC SURGERY

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THE BILLROTH I RESECTION: ITS MODIFICATIONS AND RESULTS

Pean first performed an operation in which he sutured the end of the stomach to the duodenum and decreased the circumference of the stomach by sutures placed in the vicinity of the lesser curvature. As his patient failed to recover, the fact that he first employed this procedure frequently is lost sight of. Billroth later employed this type of operation in his first successful partial gastrectomy and thereafter the operation has borne his name. In view of the fact that Billroth, a few years later in 1885, abandoned this type of anastomosis for an indirect one of stomach to jejunum which had been called the "Billroth II," it might be well to call the "Billroth I" the "Pean-Billroth operation." The reason Billroth gave for his change to using an indirect type of anastomosis from using a direct one was that only one of three patients on whom the Pean-Billroth procedure was performed recovered from the operation. This failure to recover apparently was due to leakage at the upper part of the anastomosis where the three suture lines of the anastomosis come together.

Of the various modifications of the Pean-Billroth method of direct anastomosis that of von Haberer appears to be the most satisfactory, owing to the fact that the entire circumference of the stomach is sutured to the circumference of the duodenum. In his modification the larger circumference of the stomach is decreased by interrupted sutures placed in the mucous membrane and muscularis mucosae of the gastric wall; these sutures also serve as ligatures of the larger blood vessels of the gastric submucosa.

In the first technic of the Billroth I operation the duodenum was sutured to the stomach along the lesser curvature. There seems to have been some difficulty with this procedure and there was fear of causing a diverticulum or cul-de-sac of the fundus of the stomach which appeared to be a distinct disadvantage. In later cases, "Professor Billroth, would, whenever possible, insert the duodenum into the greater curvature."

Several modifications were instituted to remove portions of the lesser curvature of the stomach to prevent the formation of the diverticulum. Among these was that of Schoemaker of The Hague (Figs. 490 and 491) and Charles H. Mayo and William J. Mayo (Fig. 492).

The modifications of the Pean-Billroth most frequently used at the Mayo Clinic have been Schoemaker's, the Mayos' and von Haberer's.¹

Technic of the Billroth I Operation and Its Modifications.—In all

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types of partial gastrectomy, the division and ligation of the branches of the gastric artery in the gastrohepatic omentum and the ligation of the branches of the gastroduodenal artery are similar. The assistant places tension on the gastroduodenal junction by grasping the anterior wall of the stomach and pulling toward the left side of the patient. At that time the surgeon inserts the index and middle fingers of the left hand through the gastrohepatic omentum to the posterior wall of the

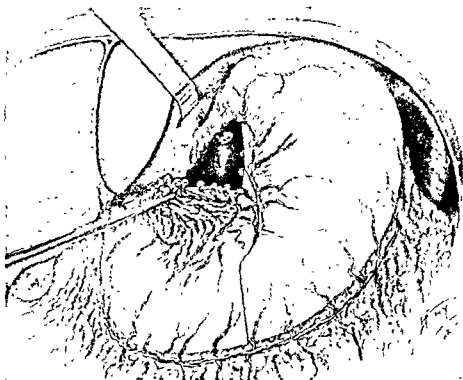


Fig. 400—Schoemaker modification of Billroth I operation. Gastric vessels have been ligated high in the gastrohepatic omentum. The portion of the gastrohepatic omentum to be removed with the tumor and the pattern of stomach to be removed are shown.

stomach and duodenum with the thumb anterior to them. The upper margin of the duodenum is wiped carefully and forceps may then be introduced between the omentum and the duodenum to permit their separation, division and ligation. By extending the index and middle fingers toward the midline posterior to the duodenum and the thumb anterior, the attachment of the gastroduodenal omentum to the duodenum can be well defined and forceps may be placed on the blood vessels (branches of the right gastro-epiploic) running through it. In cases of duodenal or gastric ulcer, the gastroduodenal omentum can be disconnected

from its attachment to the greater curvature of the stomach by repeated clamping and cutting. The line of dissection is close to the greater curvature until the left gastro-epiploic artery is encountered (Fig. 493). In cases of neoplasm of the stomach the gastrocolic omentum can be disconnected from the attachment to the transverse colon after ligation of the right gastro-epiploic vessels below the pylorus and the gastrocolic

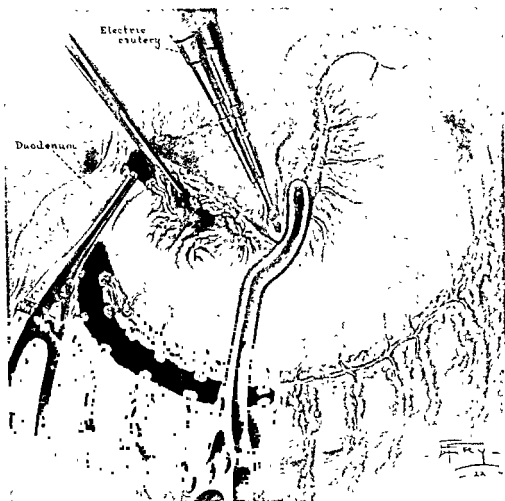


Fig. 491.—Schoemaker clamp placed across stomach. Payr clamp placed across duodenum. The portion of the stomach containing the tumor is being excised with the cautery.

omentum can be dissected with the scalpel from the transverse colon with little bleeding (Fig. 494).

A curved hemostat of sufficient gripping power to hold the cut edges of the duodenum without slipping is placed across the duodenum well below the pylorus in cases of neoplasm of the stomach or gastric ulcer (Fig. 495). In cases of duodenal ulcer this hemostat may be placed immediately distal to the duodenal ulcer or across it so that only a small

portion of the ulcer will be removed. In cases of duodenal ulcer in which the ulcer is rather far from the pylorus, an open closure of the duodenum without use of the hemostat will often have to be carried out.

A second hemostat is placed above the first one. The duodenum is transected between the clamps. The stomach is reflected upward and toward the midline, where it is held by the assistant. The gastrohepatic omentum is wiped from the lesser curvature of the stomach at the point where the left gastric artery is to be divided and ligated (Fig. 496). Three Kocher forceps are passed through the avascular portion of the gastro-



Fig. 492 —Billroth I, Mayo method. Curved hemostats placed across the stomach and duodenum so that a large portion of the lesser curvature can be removed. Inset shows method of making anastomosis.

hepatic omentum and applied across the artery and omentum which are divided distal to the two proximal forceps. The branches of the gastric artery in the gastrohepatic omentum are ligated doubly; the first ligature is a suture ligature. The distal portion of the left gastric artery is ligated with a single suture. The region on the lesser curvature denuded of serosa as a result of the separation of the gastrohepatic omentum from it and the ligation of the left gastric artery is closed with two or three interrupted sutures which approximate the serosa of the anterior and the posterior walls of the stomach. A suction pump is introduced into the stomach and any retained gastric secretions or gas is removed (Fig. 497).

In cases of duodenal or gastric ulcer from two thirds to three fourths

of the stomach is removed whereas in the presence of neoplasms of the stomach it is well to remove as much stomach above the tumor as possible and as is consistent with good postoperative gastro-intestinal function and motility. When the secretion and gas are removed from the interior of the stomach, the circumference of the stomach decreases surprisingly. This is important, since, in the Billroth-von Haberer

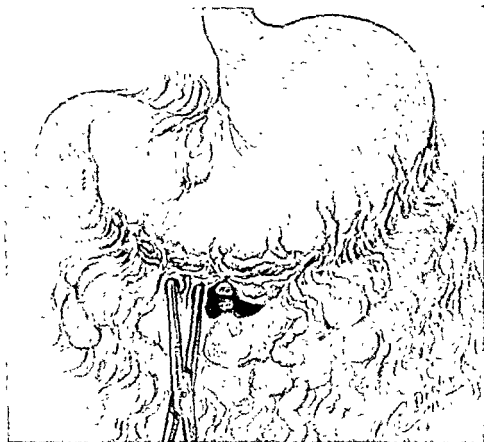


Fig. 493.—Billroth I operation. An opening has been made in the gastrocolic omentum as close to the colon as possible in order that the lesser peritoneal sac may be explored. Hemostat is shown in place on a branch of the gastro-epiploic vessels.

method, the entire circumference of the stomach is approximated to the circumference of the duodenum and any method of reducing the circumference of the stomach is worth while. Two rows of interrupted sutures are employed to approximate the greater and lesser curvatures of the stomach to the inferior and superior margins of the duodenum and a row of continuous or interrupted sutures are placed to approximate the serosal layers of the posterior wall of the stomach to the duodenum. These sutures include larger amounts of gastric serosa than of duodenal serosa. This procedure likewise tends to reduce the circumference of the

stomach. Since the stomach has been emptied of its contents, it is unnecessary to place a clamp of any sort across it. In fact, the use of such a clamp not only reduces the amount of stomach that can be removed in some cases, but in addition, so flattens the wall of the stomach that it increases considerably in circumference.

After the serosal sutures are placed posteriorly, an incision which extends to the mucous membrane is made in the posterior wall of the stomach (Fig. 498) Interrupted sutures which serve as ligatures of the



Fig. 494 —Billroth I, von Haberer technic. Gastrocolic omentum containing lymph nodes is separated from the colon. Inset shows the amount of stomach and gastrocolic and gastrohepatic omentum to be removed

branches of the gastric blood vessels, and to reef the mucous membrane and thus decrease the circumference of the stomach, are placed adjacent to each other in the mucous membrane of the posterior wall of the stomach. The mucous membrane of the stomach is incised and the curved hemostat on the duodenum is removed. The clamped crushed tissue on the duodenum is then trimmed off. Any bleeding vessels in the submucosa of the stomach are grasped and ligated. A second row of chromic catgut sutures is used to approximate the mucosa, submucosa, and

muscularis mucosae of the stomach to the duodenum. Cutting across the anterior wall of the stomach enables removal of the segment of stomach containing the tumor or gastric ulcer. If an incision is made through the mucous membrane of the anterior wall of the stomach first, the surgeon is able to pick up the blood vessels of the submucosa with hemostats and ligate them (Fig. 499).

The segment of stomach containing the lesion is removed. A point in the midportion of the mucous membrane of the anterior wall of the stomach is approximated to the midportion of the mucous membrane

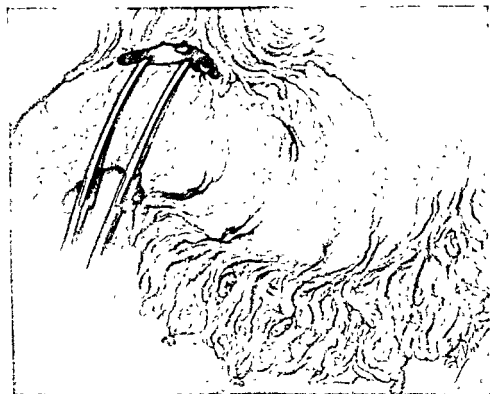


Fig. 495 —Billroth I, von Haberer method. Curved hemostats are in place across the duodenum.

and submucosa of the anterior wall of the duodenum (Fig. 500). Traction of considerable degree is placed on the two sutures at the angles of the anastomosis in order to stretch the size of the duodenum to conform more nearly to the size of the stomach. The circumference of the cut end of the duodenum can be enlarged by a small incision down the anterior wall of the duodenum at right angles to the line of suture. Further interrupted sutures are placed in the mucous membrane of the stomach and the duodenum. Each suture is placed to bisect the space between two others previously placed. Another row of sutures approximates the mucosa, submucosa and muscularis mucosae of the stomach to that of the duodenum. It is frequently advisable to start these sutures at each

angle of the anastomosis, having them meet in the midline. This assists in the more accurate approximation of the structures. The serosal layers of the stomach and the duodenum are approximated with a third row of sutures. These are usually of silk and placed interruptedly.

The upper angle of the anastomosis where it is sutured to the stomach



Fig. 406 —To ligate the left gastric artery, the vessel and right edge of stomach are palpated between the thumb and index finger and an opening is made as close to the stomach as possible. The duodenal stump has been buried in areolar tissue and fat and has been turned into the head of the pancreas. Inset, three clamps have been applied to the vessel and it will be ligated with double chromic catgut and a "sticktie."

and the duodenum with interrupted sutures is covered with a portion of gastrocolic omentum which is brought up posterior to the line of anastomosis. There is usually enough gastrocolic omentum lateral to the point of its removal for this purpose. A similar tag of omentum is used to protect the lower angle where it is maintained in position by sutures (Fig.

501). The placement of omentum in this fashion safeguards against leakage at the angles as well as on the posterior wall. If possible, the gastrohepatic omentum at the points where the gastric vessels have been ligated should be brought down and sutured to the ligated duodenal portion of the omentum. This procedure helps to relieve tension on the anastomosis. One or two interrupted sutures should be placed between the anterior wall of the stomach and the falciform ligament. They will hold the anastomosis to the right of the midline and will assist in taking

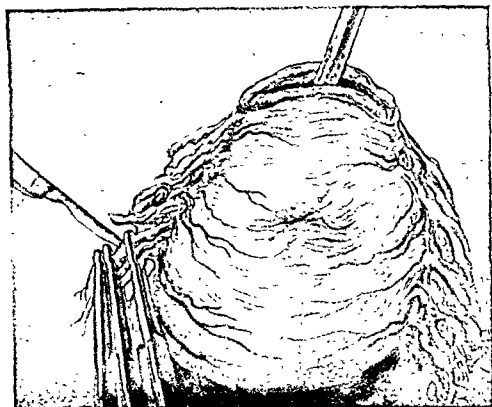


Fig. 497.—Billroth I, von Haberer method. The cut end of stomach has been reflected, exposing the branches of the gastric artery and vein and the gastrohepatic omentum. Hemostats have been placed and the vessels are about to be divided. A suction pump has been introduced into the lumen of the stomach, and is emptying it of gastric secretion and gas.

tension from the line of anastomosis (Fig. 502). If duodenal or gastric secretion has produced any soiling, from 1 pint to 1 quart (0.5 to 1 liter) of sterile water is poured slowly over the tissues and is removed with the suction pump. In this manner any gastric or duodenal secretion present is diluted and then is removed.

Billroth I, Mayo Modification.—After the gastric vessels are divided and ligated and the duodenum is divided above the curved hemostat across it, as described previously, a curved hemostat is placed transversely across the stomach at the greater curvature at the point where it

considered especially likely to occur at this angle, use of omentum to protect the posterior part of the anastomosis in the upper angle is particularly valuable in this method.

Billroth I, Schoemaker Modification.—Schoemaker devised a heavy crushing clamp patterned in such a way that when properly placed across the stomach a larger portion of the lesser curvature than of the greater may be removed. The Furniss clamp also may be used for this purpose. The method of suturing behind Schoemaker's clamp (Figs 490 and

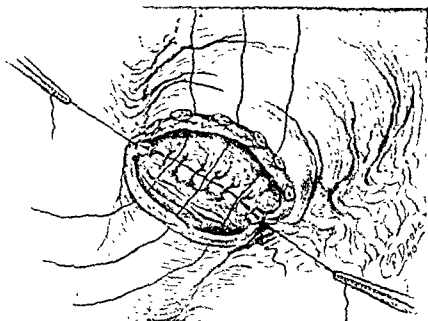


Fig 500 —Billroth I, von Haberer method. Posterior anastomosis has been completed and blood vessels of submucosa and anterior wall of stomach have been ligated. Interrupted sutures are being placed. The first suture is placed in the center in order to approximate as nearly as possible the mucous membrane of the stomach to that of the duodenum.

491) or behind the pin of the Furniss clamp, and of approximating the stomach to the duodenum is not unlike that of the method used by C. H. Mayo and W. J. Mayo.

BILLROTH II GASTRIC RESECTION AND MODIFICATIONS

The description of the Billroth II gastric resection was reported and published by von Hacker in 1885, the year in which it was devised. It differs from the Billroth I operation in that the cut ends of the stomach and duodenum are closed and the jejunum is anastomosed to the most dependent portion of the stomach in an antecolic long loop anastomosis. In 1888, von Eiselsberg first employed the modification now widely

known as the Hofmeister or Finsterer type of Billroth II operation (Fig. 505).

Polya's report in 1911 of the modification now bearing his name was more widely recognized than any of previous reports of nearly the same operation.

In this modification the cut end of the duodenum is closed and a loop of jejunum is brought up through an opening in the mesocolon to form an end-to-side anastomosis with the cut end of the stomach (Fig. 505).

After resection of the stomach for cancer, duodenal or gastric ulcer.



Fig 501.—*a*, Row of sutures approximating the peritoneal coat of the duodenum are nearly completed; separate sutures are started from the opposite sides and meet in the center. The omentum is brought posterior to the anastomosis and up over the upper pole to protect it.

the most satisfactory method of restoration of gastro-intestinal continuity has been found to be the Polya modification of the Billroth II operation. Numerous different technical procedures have been proposed to accomplish desired ends, and in many instances surgeons personally have developed slight modifications in technic that are of undoubted value. In general, the following method has been found to be satisfactory.

Technic of Posterior Polya Modification.—The two layers of peritoneum which descend from the stomach and the commencement of the duodenum enclose the left and right gastro-epiploic vessels near the

greater curvature of the stomach. The layers of peritoneum pass downward anterior to the colon for a variable distance and then turn backward and upward to the transverse colon which they enclose between the anterior and posterior layers. The continuation of these peritoneal layers after they enclose the colon until the structure becomes the mesentery of the transverse colon has many anatomically correct names. Usage, however, has limited them to the term "gastrocolic omentum" for that por-

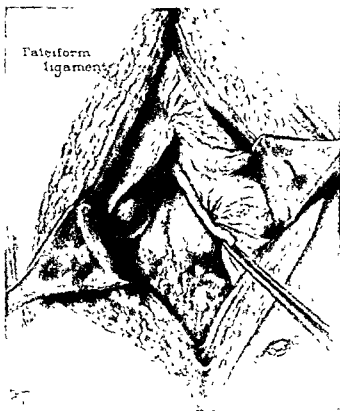


Fig 502.—Two sutures between the falciform ligament and the anterior wall of the stomach hold the anastomosis to the right of the midline and take tension from the line of anastomosis.

tion which extends between the stomach and the anterior surface of the transverse colon.

In order to obtain additional evidence concerning the operability of a neoplasm of the stomach, the lesser peritoneal sac is explored. A small opening is made in the gastrocolic omentum well over to the left, away from the lesion, and as close to the colon as possible. The branches of the gastro-epiploic vessels are doubly clamped and the portions of the vessels between the clamps are cut to enlarge the opening. The mesocolon is carefully brushed away, so that the vessels contained within it

will not be injured. If, examination within the lesser peritoneal sac reveals an operable lesion, the greater curvature can be mobilized further by continuance of dissection to the region of the pylorus as close as possible to the transverse portion of the colon. This procedure permits inclusion of the inferior gastric lymph nodes and the subpyloric lymph nodes with the portion of the stomach to be resected. The right gastroepiploic vessels then may be clamped, cut and ligated. At this point in

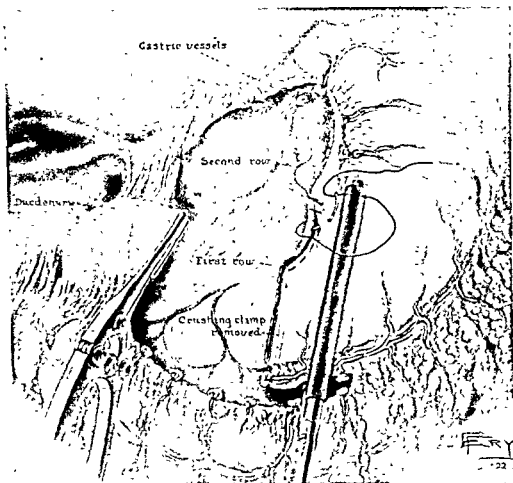


Fig. 503 —Billroth I, Mayo method. Closure of the lesser curvature.

the procedure after the contained vessels have been ligated, all the remaining hemostats may be removed. A plexus of vessels will be found in the vessels it infrequently is encountered, they must be ligated and cut with great care close to the duodenal wall.

After these vessels are ligated, the lesser curvature of the stomach is mobilized. The superior border of the duodenum may be placed on tension and a small opening may be made through the gastrocolic omentum

close to the duodenal wall. Hemostats are placed across the omentum which includes some of the branches of the gastroduodenal artery. The vessels are then divided between the hemostats and ligated. By these procedures the gastroduodenal omentum is divided to just beyond the distal line of resection. A Payr clamp then is placed on the duodenum well below the pylorus (Fig 506). A rubber-covered Doyen clamp is placed just proximal to the pylorus to prevent drainage of gastric secretion from

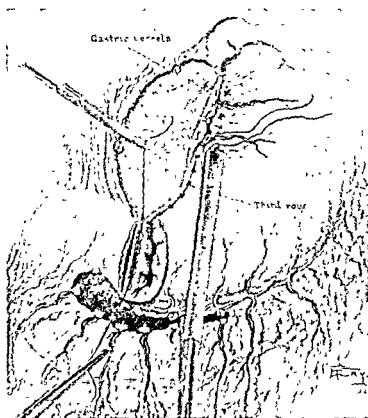


Fig 504 —Billroth I, Mayo method. Approximation of the narrowed circumference of the stomach to the duodenum

the stomach, but not in such a position as to crush the lesion. After the duodenum is divided close to the distal clamp, the stomach is retracted upward and to the left

The duodenal stump is closed with great care to prevent, if possible, the later development of a duodenal fistula. The suture material is fine chromic catgut. The first row of sutures may be placed over the clamp as shown in Figure 506 in the form of a running mattress suture. By gentle traction on the two ends, the clamp may be removed and the edges of the duodenal stump will be inverted. To invert the stump fur-

ther, the same suture material may be utilized in the second row of a continuous mattress suture to return to the starting point. Several interrupted mattress sutures of fine silk will give added strength to the closure. The stump of the duodenum then may be buried in the areolar tissue in the region of the head of the pancreas, or available visceral peritoneum from the hepatic flexure of the colon and adjacent omentum may be placed over it in such a manner as to seal off any possible leak from the closed duodenum.

At this point it is usually evident that the greater curvature of the stomach has not been mobilized sufficiently. Gentle traction may be

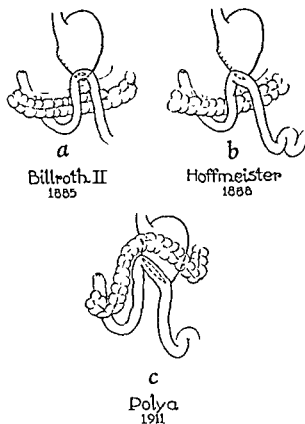


Fig 505.—a, b, and c, The Billroth II operation and some of its modifications.

applied on the gastrocolic omentum to facilitate mobilization. An excellent view then is afforded of the short vessels which extend to the stomach from the left gastro-epiploic vessels themselves. Dissection may be carried as high as desired, even to the point of complete mobilization of the greater curvatures if total gastrectomy should be indicated.

Aid in the placing of a clamp on the left gastric artery may be obtained by the exertion of traction straight forward on the stomach. The edge of the stomach may be palpated between the thumb and index finger as shown in Figure 496, and by breaking through the gastrohepatic omentum at a point beyond the line chosen for resection, the left gastric

artery may be clamped and cut. It is a wise precaution to clamp this vessel doubly in case the ligature should break, and it is also advisable to apply this ligature as a double suture ligature of chromic catgut. The distal portion of the left gastric artery is ligated after the artery is divided with a single ligature and the bared musculature on the lesser curvature of the stomach resulting from the division of the gastro-hepatic omentum and the left gastric artery is covered over; two or three

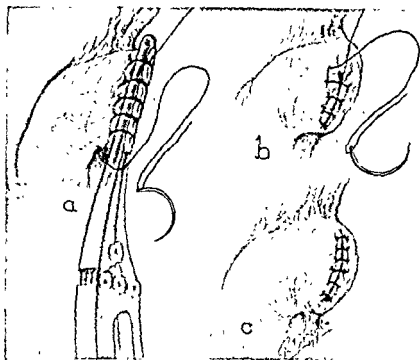


Fig. 506.—Inversion and closure of the duodenal stump, *a*, the first row of sutures utilizing a running mattress stitch, *b*, the second row of sutures consists of returning to the starting point with a continuous mattress suture and further inverting the stump, *c*, interrupted mattress sutures of fine silk form the third row of suture to reinforce the inverted stump.

interrupted sutures are used to approximate the adjacent edges of serosa of the anterior and posterior walls of the stomach.

The necessary mobilization of the stomach is now completed and a rubber-covered Doyen forceps may be applied just proximal to the determined line of resection while the stomach is held taut in a forward position. If the stomach is distended with gas or retained contents, it is advisable to insert a trocar through the divided end of the stomach and to remove the contents of the stomach by suction aspiration before the line of resection is planned.

If a retrocolic type of anastomosis is decided on, an appropriate por-

tion of the transverse part of the mesocolon should be selected in which to make an opening; this portion should not contain vessels and should be situated well to the left, so that the anastomosis may lie in as nearly a normal anatomic position as possible (Fig. 507). In certain instances attachment of the posterior cut edge of the transverse part of the mesocolon to the stomach will facilitate the operation, but this procedure makes mobilization of the stomach most difficult and under most circumstances it is simpler to attach the cut edge of the opening in the transverse portion of mesocolon to the stomach after anastomosis has been

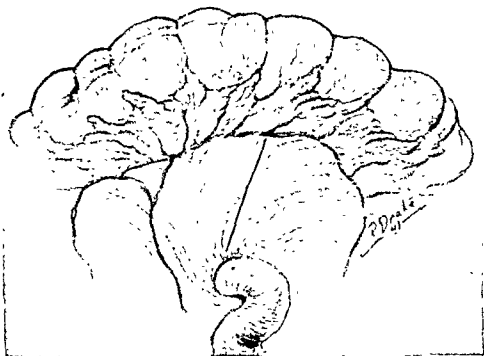


Fig. 507—Appropriate avascular region in the transverse mesocolon; the desired line of opening, the ligament of Treitz, and the proximal loop of jejunum prior to being thrust through the transverse mesocolon for the retrocolic anastomosis are shown

completed (Fig. 508). A loop of jejunum approximately 5 cm. from the ligament of Treitz is selected and is brought through the opening in the transverse mesocolon. A rubber-covered Doyen forceps is placed on the jejunum and the loop of jejunum is placed next to the retracted stomach, so that the two rubber-covered clamps are now adjacent and in such a position that the proximal limb of the jejunum lies next to the lesser curvature of the stomach and the distal limb of jejunum lies next to the greater curvature.

It has been found convenient to approximate the proximal limb of the jejunum to the lesser curvautre of the stomach with one interrupted suture of silk and to leave a long end of suture. This suture may be used

later for retraction and also to diminish the tendency toward distortion of the anastomosis, for it marks a point toward which the first line of suture may be directed. A continuous suture of silk is applied from the junction of the distal loop of jejunum with the greater curvature of the stomach. If possible only the serosal and muscular layers of the wall of the stomach and jejunum are included in these sutures. The suture material is tied and the ends are discarded (Fig 509, a)

The posterior wall of the stomach is incised through the extent of the stoma down to the gastric mucosa. The jejunum is incised down to the mucosa for a distance equal to that determined as suitable for the length

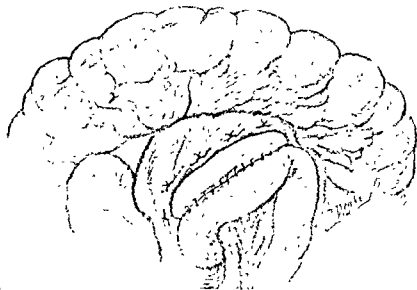


Fig 508—The anastomosis has been brought below the colon through the opening in the transverse mesocolon and anchored there by interrupted sutures of silk, approximating the edges of the opening in the mesocolon to the stomach wall

of the stoma and the second row of sutures of fine chromic catgut may be inserted as shown in Figure 509, b. This line of suture includes all layers of the wall of the stomach and jejunum, and is doubly locked at the lesser curvature of the stomach.

The stomach clamp adjacent to the one on the jejunum then may be opened to determine whether the posterior line of suture has controlled the bleeding. The advantage in having the anterior half of the stomach intact becomes apparent at this point, for the stomach acts as a retractor when the clamp is opened and prevents retraction of the stomach upward. When any bleeding points noted have been ligated, the stomach may be cut off (Fig. 509, c).

The second row of sutures posteriorly may now be continued an-

teriorly as a locking suture on the side which is next to the stomach (Fig. 510, *a* and *b*). All coats, but only a thin edge of mucous membrane are included in the sutures. The mucous membrane then will project slightly through the anastomosis and when the clamp on the stomach is removed bleeding points may be seen.

A continuous mattress suture of silk or fine chromic catgut may be applied as a second row of sutures anteriorly (Fig. 511) to invert the pro-

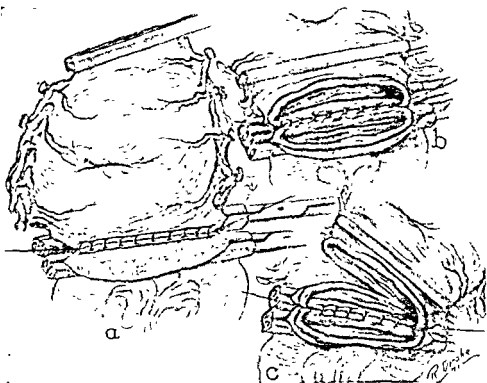


Fig. 509.—The posterior line of sutures in the anastomosis; *a*, clamps in place on the stomach and jejunum; the proximal loop of jejunum and the lesser curvature of the stomach; *b*, the proximal loop of jejunum and the lesser curvature of the stomach; *c*, the clamp on stomach has been opened and the bleeding points on the posterior suture line have been ligated; the clamp now has been closed and the stomach is being cut off.

not been sectioned; *c*, the clamp on stomach has been opened and the bleeding points on the posterior suture line have been ligated; the clamp now has been closed and the stomach is being cut off.

truding edge of mucous membrane. Multiple interrupted mattress sutures of silk may be inserted to reinforce the entire line of suture throughout the circumference of the anastomosis.

The next step in the operation is the anchoring of the anastomosis below the opening in the transverse portion of the mesocolon. In order to accomplish this the colon may be retracted upward and multiple interrupted sutures of silk may be inserted so that the stomach projects approximately 2 cm. below this opening (Fig. 508). The remaining por-

tion of stomach should be in as nearly a normal position as possible in order to diminish the possibility of angulation of the jejunum at the site of the anastomosis or immediately distal to it. If the posterior edge of the transverse mesocolon has been sutured to the stomach prior to the anastomosis, the anastomosis may be pushed through the opening in the transverse mesocolon from above and the anterior edge of the transverse mesocolon may be sutured to the stomach above the site of the anastomosis

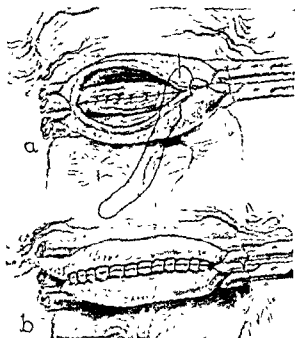
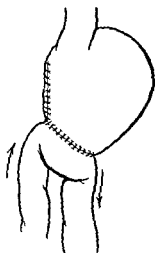


Fig. 510.—The anterior line of sutures; a, the second row of sutures in the anterior line is continued anteriorly, the sutures are locked on the stomach side; all coats are included, b, this row of sutures is completed; the clamps will be removed to view bleeding points from the anterior portion of the suture line

Technic of the Anterior Polya Operation.—The anterior Polya operation is performed in approximately the same manner as the posterior Polya. The jejunum, however, is brought up anterior to the colon and is anastomosed to the stomach approximately 12 to 16 cm from the ligament of Treitz; the distance depends on the indications for the procedure. This type of anastomosis is indicated particularly when resection is unusually high or when the transverse mesocolon is short and contains much fat.

Hofmeister Modification of the Polya Operation.—In certain instances it may be advisable to use the Hofmeister method. The anterior or posterior Polya anastomosis, however, will furnish the same mechanical

right angles to the lesser curvature of the stomach is removed. By this means the circumference of the opening in the stomach which is to be anastomosed to the jejunum is reduced and a valve is formed. The procedure is a valuable way of removing gastric ulcers located high on the lesser curvature of the stomach. More of the lesser curvature of the stomach is removed in the Hofmeister modification of the Polya operation in the same manner as the lesser curvature is removed in the Mayo



Posterior Polya
(Hofmeister)

Fig 512 —Hofmeister modification of the Polya operation showing the excision of a portion of the lesser curvature of the stomach

modification of the Billroth I operation, (Fig 492). The finished procedure is shown in Figure 512

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APPENDICITIS

With Consideration of the Newer Drugs in Appendiceal Peritonitis

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On the basis of present knowledge the problem of the cause of appendicitis, one of the commonest of diseases requiring surgical treatment, appears to be still unsolved. In spite of extensive investigation, beyond the limit of this discussion, the reasons for the start of infection in the appendix or for the onset of obstruction by a fecalith are still obscure. Even the cause of the formation of a fecalith is unknown. What environmental factors, what dietary or other habits, what local anatomic or physiologic variations determine the formation of an appendiceal concretion in one individual and not in another must remain matter for speculation. The obvious implication of this ignorance is, of course, that no rationale can exist for the prophylaxis of the disease. One can expect the incidence of appendicitis to remain approximately constant except for the possible influence of genetic or environmental factors still unknown to us. We do not know how to prevent the disease.

On the other hand, we know how to prevent its ravages. By early removal of the diseased appendix death can be avoided and the degree of illness can be made comparatively trivial. A summary of the knowledge that makes this possible together with a brief consideration of the results in 1005 recent consecutive cases under modern therapeutic conditions, to be compared with an earlier series, constitutes the substance of this discussion.

PATHOLOGY

The pathologic problem of appendicitis is divided into two phases, namely, (1) appendicitis proper, in which necrosis and infection are limited to the appendix itself, and (2) appendiceal peritonitis in which infection has spread to the peritoneum. The former represents the stage of the disease during which early surgical treatment will result almost invariably in prompt complete recovery. The latter is the stage, like peritonitis of any origin, in which recovery is uncertain and morbidity

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prolonged. Fundamentally the purpose of the treatment of appendicitis is the prevention of the second stage.

The Contaminated Peritoneum.—The dividing line between the two stages has been differently fixed by different observers. Most writers employ the obvious data furnished by gross observation at the time of appendectomy. If the appendix is perforated and the peritoneum presents fibrin, cloudy and perhaps foul fluid, dulling of its surface and hyperemia, the case is classified as appendiceal peritonitis. A microscopic section through the serosa and subserosa of the peritoneum of surfaces near the appendix would show all the changes of acute inflammation and the pathologist would rightly report "acute peritonitis." A considerable number of such patients will continue to be ill with peritonitis after the removal of the diseased appendix which has initiated the peritonitis. However, some of these patients will recover promptly after appendectomy with just as smooth a postoperative course as though the pathologic appearance of acute peritonitis were not present. This discrepancy has led us as well as others to the concept of the *contaminated peritoneum*, analogous to the contaminated wound which heals without infection. Just as one cannot predict what contaminated wound will heal cleanly, so at the time of operation one cannot predict the case of perforated appendicitis in which there will be recovery without peritonitis. The data for classification can be known only after the postoperative period. Obviously the factors that determine in which direction the disease will proceed are identical with those that govern the establishment or absence of infection in the accidental wound, namely dose and virulence of organisms, amount of necrotic tissue, general and local resistance, and the interval between contamination and the removal of the source of contamination. Obviously also most cases of contaminated peritoneum are cases in which perforation has occurred shortly before operation.

The reason for making this distinction is twofold. The first is to provide a rational basis for therapeutic decision, to be elaborated later. A statement of the second may be quoted from a previous discussion.¹ "Any statistical study which groups all perforations of the appendix under the head of peritonitis is presenting a distorted picture of the

The cases of contaminated peritoneum can justly be included, after the postoperative course is known, in the group of uncomplicated appendicitis, as was done by Lehman and Parker.² Inasmuch as, by definition, all these cases recover (with the exception of rare deaths from complications unrelated to the intra-abdominal disease) this procedure does not alter the mortality rate for the simple group. On the other hand, by excluding the contaminated peritoneum, it definitely presents a more accurate picture of true peritonitis."

In classifying the material from this clinic we include the cases of

perforation that do not evidence an independent peritonitis in the group of simple appendicitis; i.e., appendicitis with infection limited to the appendix.

Types of Pathologic Processes in the Appendix.—Having formulated a rational dividing line between appendicitis and appendicitis with peritonitis, let us revert to the pathology of the appendix itself. It has long been recognized that appendicitis presents two quite different pathologic processes reflected in some degree in the clinical course. The two are often associated and under those circumstances it is not always clear which precedes the other. When seen independently, however, there is no missing the differences. The first is an infection of the appendix unrelated to obstruction, the so-called *cellulitis* of the appendix, in which it is probable that ulceration at the base of a mucosal crypt serves as the portal of entry. This type has a relatively slow progress with relatively mild symptoms. Pathologically it presents early the red, uniformly swollen appendix without necrosis and with no obstruction of its lumen, except the narrowing incident to edema. Thrombosis of the blood vessels and consequent gangrene and perforation with resulting contamination of the peritoneum occur late.

The second type is the *obstructed appendix*, which in contrast to the first type advances rapidly and with violent symptoms, often resembling in degree of pain and amount of vomiting the symptoms of intestinal obstruction. Occlusion of the appendiceal lumen occurs most commonly by impaction of a fecalith, but may be due to tumor, scar, parasites or rarely ingested foreign bodies. Often the precipitating factor may be the swelling incident to cellulitis of the appendix which increases the pressure on a fecalith and thereby obstructs drainage. In other instances a chance peristaltic wave may wedge the foreign body against a pre-existing narrow segment of the lumen resulting from scar or anatomic peculiarity. When obstruction occurs pressure is built up distally by continued mucosal secretion and the action of bacteria on the content. This pressure and infection may cause early occlusion of capillaries or even thrombosis of arterioles and venules and consequent total necrosis of the organ distal to the obstruction, which may advance to an irreversible stage within a few hours of the onset of symptoms. The picture at operation is that of gangrenous appendicitis. The wall of the gangrenous appendix is no longer a barrier to the passage of bacteria from its lumen. Widespread contamination of the peritoneum may therefore begin before actual gross perforation of the gangrenous organ can be seen. This is the most dangerous time of appendicitis since the infection has already protected the inflammatory process from being initiated. One does not speak of enteritis in connection with strangulation of bowel in a hernia sac.

Short of total distal gangrene, the pathologic processes of the ob-

structed appendix may follow other courses. Pressure may be built up less rapidly so that only the capillaries of the mucosa may be first affected. Necrosis of the mucosa then occurs, opening a portal of invasion for organisms into the still living tissues of the submucosa and muscularis, and resulting in a true appendicitis, a cellulitis of the appendiceal wall. Later total gangrene may eventuate. More commonly, however, when the obstruction is due to a fecalith, one sees a local pressure point of necrosis over the position of the foreign body. This may become com-

halted. Such a perforation, however, obviously causes marked contamination of the peritoneum.

The Course of Untreated Appendicitis.—*The later course of untreated*

always seemed to us somewhat doubtful in view of the frequency of right lower quadrant pain in cases in which acute appendicitis is proven not to be present. If such an event occurs it must represent either spontaneous subsidence of an early cellulitis of the appendix, which is not at all an impossible concept, or the dislodgement of an already impacted concretion, which is harder to postulate.

If the disease progresses in the appendix and the peritoneum becomes contaminated, several alternative courses are possible. If perforation is delayed and the early contamination is small in amount and low in virulence so that a protective inflammatory reaction is set up in the peritoneal surfaces of structures surrounding the appendix, then perforation will occur into an area already prepared to combat contamination or into an area about which a fibrinous adhesive process has created a walled-off zone of actively inflamed serosa. If, on the contrary, perforation is early and the contamination severe, then the contents of the appendix will be deposited in a peritoneum not prepared to defend itself or to wall off the dangerous area. Recent work by Kay and Lockwood² suggests that the availability of fibrin for agglutination of peritoneal surfaces may depend somewhat on the titer of antifibrinolytic substances in the blood of the experimental animal.

These observations suggest an additional explanation of varying potencies of local resistance and may prove of clinical importance. The result of unresisted contamination of the peritoneum is, of course, peritonitis spreading actively to involve varying areas up to total infection of the abdominal cavity—general peritonitis. Detailed consideration of the pathology and treatment of peritonitis is beyond the scope of this discussion, which is concerned only with the prevention of peritonitis by adequate treatment of appendicitis.

DIAGNOSIS

Typical Appendicitis.—Appendicitis is not an easy disease to diagnose except when it appears in the classical form. Unfortunately the textbook picture of appendicitis in its early stages is seen less often than atypical forms. One need hardly describe it. Symptomatically there is first intermittent cramping pain of varying severity located in the epigastric region or about the umbilicus. Shortly afterward nausea occurs, followed by one or two episodes of vomiting. Later, by few or many hours, the pain shifts to the right lower quadrant where it becomes relatively constant. Vomiting may or may not persist, depending perhaps on the presence or absence of appendiceal obstruction. Curiously, the initiation of pain may be preceded by a period of malaise and inappetence of up to twenty-four hours' duration. The bowels are not affected.

On physical examination one finds in the typical case sharply limited tenderness at McBurney's point accompanied by localized involuntary spasm. These are the only constant typical signs, although tenderness high in the right pelvis detected by digital rectal examination may occur. The measurable data include a minimal to moderate increase in all factors. The pulse is increased 10 to 20 beats per minute, the temperature ranges 1° to 2°F. above normal and the white cell count ranges from 8000 to 12,000 with an increased preponderance of polymorphonuclear forms and a slight incidence of premature cells. The examination of all other functions yields findings within the limits of normal.

When this clinical picture is present the presumptive diagnosis of acute appendicitis will rarely be in error. However, as we have said, the complete picture is not common. One may find a typical history with equivocal physical findings, typical physical findings with a bizarre history, and any variety of variation from the typical temperature, pulse and laboratory observations. On the whole, the history seems most reliable. If

no
tis cannot be ruled out, and the second is to determine the presence or absence of peritonitis. Both present real difficulty.

Differential Diagnosis.—In approaching the diagnosis of appendicitis, the surgeon must consider all sorts of causes for right-sided abdominal pain, including gastroenteritis, poisonings, the exanthemata, disease of the urinary tract, ruptured ovarian follicle, mesenteric lymphadenitis, ectopic pregnancy, cholecystitis, lumbosacral arthritis, sacroiliac disease, pneumonia, pleurisy, coronary disease, meningitis, psychoneurosis and other conditions. Space will not permit the detailed discussion of the differential diagnosis of all these diseases. Suffice it to say that (1) a careful complete systems' history, (2) a complete physical examination including a minimal neurologic study, and (3) routine laboratory examination including a study of the stained blood smear will serve to rule out

many of the alternative diagnoses. Possibly such study will suggest special investigations that must be made before some of the alternatives can be discarded. A catheterization of the right ureter may be indicated or, especially, white cell individual.

alert for an alternative condition that will affect the operative risk. It is much less serious to operate for supposed appendicitis when the disease is a ruptured follicle or a blocked ureter than when it is a coronary occlusion or pneumonia.

It is unfortunate that the question of operating under a mistaken diagnosis of appendicitis must arise; but there are two reasons why it should arise. The first has already been mentioned, namely, the atypical and confusing picture that actual appendicitis frequently presents. The

before the introduction of chemotherapy and antibiotics, operation for simple appendicitis in 829 cases resulted in a mortality of 0.24 per cent. The total mortality of 240 cases of peritonitis arising from appendicitis, including localized and general peritonitis but excluding the contaminated peritoneum, was 13.7 per cent. The risk in the neglected case, the case in which the diagnosis of appendicitis had been missed either by the patient's failure to consult a doctor or by the doctor himself, was at that time, therefore, nearly sixty times the risk of the diagnosed case. In a later series to be presented below the contrast is less, but it is still striking. Even with the aid of chemotherapy and antibiotics, the risk of the missed diagnosis is thirteen times that of the diagnosed case. Such ratios put pressure on the surgeon for appendectomy. No gambler would accept such odds on his own life.

On accc and (2) tl that any tions for the disease when it is not present. Their number should not be high. The surgeon can accept a wrong preoperative diagnosis with a good conscience, provided only that he has honestly considered all other possibilities, including especially those that affect operative risk, and has seen to it that his patient has had adequate preoperative study as outlined above. Finally, his conscience cannot be clear unless the patient and

salve to the mistaken surgeon's conscience. It is not mentioned since it can be too easy an escape for the surgeon who operates after inadequate study.

Determination of Stage of Disease.—Let us now turn to the second

aspect of the clinical problem, the necessity to determine as nearly as possible the stage of the disease, once appendicitis has been established as the presumptive diagnosis. There is no equivocation possible to the statement that the treatment of acute appendicitis is appendectomy; but when the contamination has reached the peritoneum the wisdom of appendectomy in all cases is at least debatable. These matters will be discussed later.

Let it be said here only that the surgeon is obligated to make up his mind if possible whether either a local or a general peritonitis has become established. The often cited cessation of pain when perforation occurs is a most unreliable guide, one which the senior author has been able to recognize not more than two or three times in a long experience with the disease. The time factor is helpful, but one must guard against the treatment of appendicitis by time-table. Duration of symptoms as a guide to treatment was popularized early in the history of the disease by A. J. Ochsner⁵ who recognized the harm done by the then clumsy intrusion into the abdomen during the period of spreading infection. It has since been learned that time as the only basis for decision cannot be justified.

The surgeon's judgment must be founded on the time factor together with the severity of symptoms, signs and physiologic deviations from normal. Obvious illness accompanied by widespread abdominal tenderness and spasm and by marked sepsis and particularly by a rapid pulse rate must mean a generalized peritonitis even if it occurs on the second day of the disease. In the same sense one can diagnose with fair accuracy a simple appendicitis on the fourth or fifth day if the physical signs remain localized and the evidence of sepsis is minimal. A localized peritonitis can be recognized when a mass is noted either before or after an anesthetic. Furthermore, a localized peritonitis can be suspected in the absence of a mass if the physical signs remain localized and the signs of sepsis are marked. Employing all known data in the case, the surgeon should attempt to obtain some sort of idea of the extent to which the process has spread. Often enough he will remain uncertain.

TREATMENT

The treatment of appendicitis as already twice mentioned is appendectomy as early in the disease as the diagnosis can be made. How early in the disease it can be made depends on two factors, (1) the patient or the patient's family and (2) the family doctor. The latter is helpless in the individual case if "home remedies," including particularly cathartics, have been administered for a period of two or three days and he is called upon only when the serious illness of peritonitis has appeared. The medical profession as a whole, including the family doctor, is at least partly to blame for the frequent late appeal to the physician. We have not stressed on enough occasions that persistent abdominal pain is a dangerous symptom requiring expert diagnosis. The profession has not taught, and perhaps has not in individual instances accepted, a proper perspective on

constipation and has allowed the family medicine cabinet to contain the most explosive cathartics with the assumption that they are safe to use before the doctor is called. Too often the assumption amounts to a directive, particularly when the doctor prescribes cathartics without examination of the patient. Even after fifty years of publicity about appendicitis patients still try to cure abdominal pains by purging and some doctors try to cure them by the same method. At a rural county medical society meeting not over fifteen years ago a physician who performed much of the surgery of his own clientele remarked that appendicitis is easy to diagnose: "Give 'em castor oil and if they don't get well, it's appendicitis."

When there is a remedy, appendectomy, that is almost completely effective if applied in the early stage of a disease, the tragedy of the occurrence of late cases in which the remedy is one-thirteenth as effective becomes poignant. The physician can do much by preaching continuously in his practice the risk of abdominal pain. Above all, he can protect his own clientele by refusing to prescribe for abdominal pain without an examination of the abdomen. If there is slight fever and localized tenderness, then a leukocyte count is in order. Only the most urgent of other appointments should keep him from the bedside of the patient whose abdominal pain is severe enough to cause him to seek help. If he remains uncertain, repeated observation at short intervals must be made, or, preferably, the patient must be placed in a hospital where frequent observation is easily carried out. The prime factors in diminution of death from this common disease are early recognition and prompt appendectomy.

Appendectomy in Peritonitis.—Although this discussion is limited to the treatment of acute appendicitis, the latter so merges with peritonitis that it also must be briefly considered. The one dictum, oft repeated, is that appendectomy in simple appendicitis is the only treatment. Obviously from our definition appendicitis with a contaminated peritoneum is also amenable to appendectomy in all instances and should be so treated. There remain then two groups to consider, localized peritonitis and spreading to general peritonitis.

There are those who affirm that appendectomy is indicated in all cases of peritonitis from appendicitis, no matter what the stage of the pathologic process may be. However, careful studies by several groups including our own have shown that conservative treatment of localized peritonitis, with hemo-bidity therapy and than surgical drainage with or without appendectomy. There is good biologic reason to explain these observations. A patient who presents a localized peritonitis, and is stated that he is Further-verse circumstances—work, activity, gastrointestinal stimulation from food and catharsis, degrees of dehydration and starvation. Give rest to his body

and particularly to his gastrointestinal tract, correct his physiologic deficiencies, furnish him parenteral sustenance, including protein sufficient to manufacture globulin for antibodies, and it may well be expected that he will intensify the effectiveness of his already effective resistance. Our experience has shown that probably 75 per cent of patients presenting localized peritonitis will recover without operation. In such cases appendectomy two or three months later is always advised. In thus supporting nonoperative treatment we must reemphasize that we are no longer concerned with appendicitis alone but with its much more serious sequel, peritonitis.

The rationale of the treatment of spreading peritonitis is not so clear-cut. In the first place, since the clinical distinction between this phase of the disease and the contaminated peritoneum is difficult and often impossible, as indicated earlier, one must take the position that immediate appendectomy is indicated in all cases except those in which the wide extent of signs and the severity of the picture make a diagnosis of established peritonitis inescapable. Often enough a case at the fourth or fifth day presenting evidences of spreading peritonitis will prove after appendectomy to represent only a contaminated peritoneum. It is in the group of unmistakably established peritonitis that opinion is not definite. One can argue *a priori* either (1) that abdominal intervention will depress peritoneal resistance or (2) that it is essential to remove the offending source of peritoneal contamination. Under our definition the incidence of cases classified in this group is low (59 cases out of 1029 cases of acute appendicitis in our earlier series² and 82 cases out of 1005 in our later series, Table 1), and therefore statistically significant data in a condition presenting such manifold variations are slow to accumulate. On the whole we have tended to remove the appendix without drainage in such cases more often in recent years than earlier. This tendency has undoubtedly been increased by the availability of presumably effective chemotherapeutic and antibiotic substances.

CHEMOTHERAPY AND ANTIBIOTICS

What has been said so far offers nothing new. It is recognized, however, that much of the point of view presented is not accepted by all surgeons. In the transition period of treatment through which we are passing these differences of opinion may lose significance. If antibacterial drugs are actually effective supplements to surgical treatment, appendectomy may become the treatment of choice no matter what stage of peritonitis the patient presents. The determination of such effectiveness thus becomes of prime importance. Whether or not we in this institution have shifted our practice to more frequent appendectomy in localized and spreading peritonitis will be studied in a more detailed analysis of the recent series here reported in a preliminary way.

Many surgeons have offered evidence that various of the available drugs affect favorably the morbidity and mortality in appendiceal peri-

tonitis.^{6, 7, 8, 9, 10} Space will not permit a review of this evidence. The specific drug of choice and the varying routes of administration so complicate the picture that a clear-cut demonstration in clinical material is difficult. We wish here to present data to add to those already published.

One thousand and five cases of proven acute appendicitis occurring consecutively during the years 1943-1948 have been subjected to partial analysis in an attempt to evaluate the role of the newer drugs. A more detailed study of this material is under preparation for future presentation. Comparison of the mortality rates between this series and a series of equal size occurring during 1933-1937 inclusive² is presented in Table 1. It is seen that the mortality for simple appendicitis is the same in the two periods, probably representing the minimal hazards of major surgery. One of the two deaths in the present series was due to the anesthetic and the other resulted from an unyielding adynamic ileus without peritonitis,

TABLE 1
MORTALITY

Series		Simple Appendicitis			Appendicitis Peritoneal Infection									Total		
					Localized			Diffuse			Total					
		Cases	Deaths	Mortality, per cent	Cases	Deaths	Mortality, per cent	Cases	Deaths	Mortality, per cent	Cases	Deaths	Mortality, per cent	Cases	Deaths	Mortality, per cent
1933 to 1937		829	2	0.24	181	9	5.0	59	24	40.6	240	33	13.7	1069	35	3.27
1943 to 1948		813	2	0.24	110	0	0.0	82	6	7.3	192	6	3.1	1005	8	0.8

as demonstrated at a second exploratory operation. Many of the 813 patients with simple appendicitis received various combinations of penicillin, sulfonamide drugs and streptomycin given either locally or systemically or both. In those cases in which perforation had not occurred, it is believed that drug treatment did not contribute to recovery. On the other hand, in the cases of contaminated peritoneum, which are included in the table under the heading "simple appendicitis," drug treatment may have affected the incidence of independent peritoneal infection. Eighty-five of the 813 cases of simple appendicitis were cases of contaminated peritoneum and, of these, 68 received specific drug treatment.

It is impossible to judge whether the incidence of peritonitis actually has occurred.

istration are so great that a close analysis of each drug independently is impossible. In the present series of 192 cases of appendiceal peritonitis, 171 received one or more of the following drugs—penicillin, sulfanilamide, sulfadiazine and streptomycin—by local or systemic administration or by both. The various combinations of drugs and routes of administration numbered 17 and no one combination was employed in more than 44 cases. This was the combination of penicillin and sulfadiazine, both given systemically; the 44 cases were divided into 24 cases of local peritonitis and 20 of diffuse peritonitis. From these facts the difficulty of estimating the effects of a single drug is obvious.

The one fact that can be emphasized is that the last death in this series occurred in September 1946 and that the use of streptomycin began in October 1946. There have been 416 consecutive cases without a death. Of these, 70 were cases of either localized or diffuse peritonitis and, of the 70, 43 received streptomycin in combination with penicillin and occasionally sulfadiazine. Some of these patients were extremely ill with a wholly

TABLE 2
PERCENTAGE DECLINE IN MORTALITY

	Mortality 1933-1937 Inclusive	Mortality 1943-1948 Inclusive	Decline in Mortality
Localized peritonitis	13.7%	3.1%	77.3%
Diffuse peritonitis	3.27%	0.8%	75.8%
Total	6.88%	3.05%	55.7%

unfavorable prognosis when first seen. This seems to represent suggestive evidence of the value of streptomycin.

The striking decline in the mortality of appendiceal peritonitis in the later period as compared with the earlier period (Table 1) must be interpreted with caution. There were no deaths from localized peritonitis in the years 1943-1948 and 5.0 per cent mortality in the years 1933-1937. The mortality for diffuse peritonitis in the later series is about one-sixth of that in the earlier series. Similarly the mortalities for all cases of appendiceal peritonitis and for the total series of 1005 cases are each about one-quarter that of the earlier figures.

Lehman and Becker,¹¹ reporting in 1946 on the total surgical mortality at this institution for the years 1934 to 1945 inclusive, emphasized the fallacy of ascribing a drop in mortality rate of a disease to any single therapeutic measure without knowledge of the drop in mortality of all surgical diseases during the same period.

This comparison is given in Table 2. It will be seen that the mortality for localized peritonitis dropped from 13.7 per cent to 3 per cent and the mortality for diffuse peritonitis from 3.27 per cent to 0.8 per cent, whereas the total mortality dropped from 6.88 per cent to 3.05 per cent. Since the

chemotherapeutic drugs and the antibiotics were the chief added elements in treatment in the later period, their effectiveness is probably evidenced.

play a part in the decline in total mortality, some of which is also due in part to antibiotics and chemotherapy. Appendiceal peritonitis is an infection for which these drugs may or may not be specific. Since they are not specific for a considerable proportion of cases included in the total surgical mortality, and since the degree of improvement in results in peritonitis is strikingly greater than the degree of improvement in results in all surgical disease, it seems proper to ascribe to them an important part of the improvement in results in peritonitis. However, it must be remembered that the present analysis is incomplete. The more detailed study to follow may reveal other differences between the two series.

SUMMARY

1. The pathology, diagnosis and treatment of acute appendicitis without and with peritonitis have been reviewed.
2. The concept of the contaminated peritoneum has been emphasized.
3. A preliminary analysis of 1005 consecutive cases of acute appendicitis during the years 1913-1948 inclusive has revealed a striking decline in mortality as compared with a previous study for the years 1933-1937 inclusive.
4. This improvement in results has been ascribed in part to the use of sulfonamides and antibiotics.

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ACUTE INTESTINAL OBSTRUCTION

CLARENCE DENNIS, M.D., PH.D.*

In many quarters, acute complete bowel obstruction is considered rare. An estimate of the frequency with which it is seen in the 450 beds at the University of Minnesota Hospitals suggests that one new small bowel obstruction is seen on the average once each two weeks¹⁰ and one new colon obstruction about once a month.⁷ This is perhaps a higher incidence than might be expected, but Dr. O. H. Wangensteen has stimulated much wholesome interest in this subject, as in many others, in our community, and therefore more cases are recognized and referred to his service here than would otherwise be the case. Of all cases of cancer of the colon coming to the University of Minnesota Hospitals in 1938 to 1944, 9.5 per cent presented themselves with acute complete obstruction.

Review of several series of cases has led to the conviction that a large share of our failures in the therapy of bowel obstruction may be attributed to inaccurate diagnosis. The precise differentiation of colic from ileac obstruction, of paralytic ileus from mechanical obstruction, of strangulating from simple bowel obstruction, of high from low ileac obstruction, must precede consistently successful management.

In the past fifteen years, Wangensteen and his associates here, and later others in various quarters, have demonstrated the possibility of successful separation of the cases of small bowel obstruction amenable to nonoperative intubation-decompression therapy in a high percentage of cases. The appearance of strangulating lesions which were not diagnosed before surgery, and which in retrospect presented no clues which might have suggested the presence of strangulation, proved disturbing to our entire group. The development of the Wangensteen aseptic decompressive enterotomy for evacuation of the distended bowel without contamination has provided the means to facilitate early operative intervention in almost all cases of intestinal obstruction regardless of the degree of distention. The recognition of the type and level of obstruction has thus become less imperative perhaps than earlier, in the choice of operative as against nonoperative management, but it is no less important in the decision as to the placement and type of incision to be employed and as to the urgency with which preparation and intervention are dictated. These diagnostic matters have been amply discussed else-

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where,^{4 10. 15} and the available space will be used in preference for the representation of certain techniques

MECHANISMS OF OBSTRUCTION

A review of several years' experience at this clinic has given in broad outline the underlying mechanisms and the relative frequency thereof. In obstructions between the ligament of Treitz and the ileocecal junction, external hernias account for about 40 per cent and adhesions and bands about 50 per cent. In most years, all other mechanisms comprise only 10 per cent. These include volvulus, intussusception, gallstone obstruction, internal hernia, neoplasm and others. About 35 to 40 per cent of small bowel obstructions could well be treated by nonsurgical means, if we could but select the proper cases with unfailing accuracy.

In the colon, primary carcinoma has accounted for two-thirds of our obstructions, and of these, six out of seven have involved the left colon. Half the remainder have been due to sigmoid volvulus. Other mechanisms include diverticulitis, other pelvic infection, secondary neoplasms, and adhesions.

MECHANISMS OF DEATH IN UNTREATED CASES

A full appreciation of the available therapeutic measures must be predicated upon an awareness of the lethal factors in the several types of obstruction. Strangulation obstruction, whether volvulus of the cecum or sigmoid, or some type of ileac involvement, may kill by sufficient engorgement to lead, in conjunction with vomiting, to drastic reduction of blood volume and death in shock. Failing this, it may kill by perforation and peritonitis, or by sepsis if the necrotic bowel should be enclosed, as in a hernia sac or in intussusception.

In the small gut, obstructions high in the ileum or in the jejunum lead to excessive vomiting of fluid containing most of the salivary, gastric, biliary, pancreatic and duodenal secretions—a total of 5 to 12 liters a day. Rapid dehydration, acute chloride loss and secondary uremia are rapidly fatal, if not corrected. If the block is low in the ileum, most of this fluid is reabsorbed, and chemical imbalances are relatively unimportant. Here, however, the consensus is that lethal transperitoneal absorption of toxic bacterial products may result from mucosal damage due to vascular impairment, which in turn is secondary to prolonged distention.

In the colon, the process which kills, except occasionally in volvulus, is tension perforation and peritonitis. Although this rarely does occur at the obstructing carcinoma, the vast majority of reported cases have perforated at the cecum. Competence of the ileocecal valve, which renders the colon a closed loop, with ever rising pressure due to continued discharge of material from the ileum, leads to tension ischemia of the anterior cecal wall, the thinnest area and the largest in diameter. Incompetence of the valve, however, is no guarantee against cecal perforation.

DIAGNOSTIC CONSIDERATIONS

Complete small bowel obstruction is characterized by persistent vomiting, which becomes fecal in character in three to five days.⁶ There are also regularly acute increases in abdominal pain (cramps) which come every three to ten minutes except in very late cases. Characteristically these cramps are associated with abdominal sounds of pitch higher than high C (or 512 per sec.). The degree of distention depends on the level of



Fig 513.—Roentgen picture of abdomen of a patient with complete obstruction in the pelvic colon. In this case the ileocecal valve has herniated into the ileum, and true "closed loop" O H. Intestinal Obstructions, Ed 2

the obstruction, being greater in the lower ones. X-ray signs are discussed elsewhere.⁴

Recognition of strangulation must be early to be helpful if one is to treat any cases by nonsurgical measures. The findings, any one of which is indicative of strangulation, are: history of sudden onset, back pain, shock, leukocytosis, fever, and signs of peritoneal irritation such as spasm and rebound tenderness. X-ray findings suggestive of a double coffee

bean appearance should be viewed with suspicion of strangulation. With our recent adoption of exploration of nearly all cases of small bowel obstruction, early recognition of strangulation has assumed less importance, although it may indicate particular urgency in some cases.

In colic obstruction, most cases result from carcinoma primary in the colic wall. Here a history may be obtained of gradually increasing constipation, perhaps alternating with diarrhea, of black or bloody stools, of weight loss over some months, of previous meteorism or even acute bouts of distention and obstruction, relenting after enemas. With acute

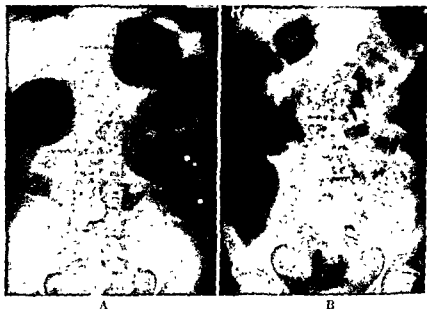


Fig 514.—Examples of varying amounts of gas visible in the small bowel in

obstruction from any cause, initial vomiting is the rule, but only half vomit more than two or at most three times, in contrast to the situation in ileac obstruction. Fecal vomiting is rarely seen in colic obstruction (8 per cent),⁷ it is a result of the length of time material has been in the bowel rather than the level in question.

In colic obstruction, peristaltic rushes and cramps come at intervals of more than ten minutes, often hours or half-days. Clinical distention may

In a six year review of colic obstructions at this clinic in 1922, all cases

was made to clarify the x-ray findings. Of forty-one cases of acute colic obstruction, thirteen (31.7 per cent) presented no x-ray evidence of gas in the ileum and of classical marked colic distention (Fig. 513). Twelve (29.3 per cent) showed just discernible gas in the ileum (Fig. 514A). Thirteen (31.7 per cent) showed definite distention of the small intestine (Fig. 514, B). Three (7.3 per cent) showed distention most marked



Fig 515 —Example of varying amounts of gas visible in the small bowel in cases of colic obstruction. Scout film of the abdomen. Small bowel distention more marked than colic distention (7 per cent of series). (From Surgery, Vol. 15.)

in the ileum (Fig. 515), and presented a clinical picture in two of the cases which could easily be confused with small bowel obstruction.

It is apparent, therefore, that about two-thirds of these cases presented diagnostically conclusive x-ray evidence of colic obstruction and that careful evaluation of the history and physical findings were in addition essential in the others. The lesions of the right colon are most prone to be accompanied by excessive vomiting and marked x-ray evidence of ileac distention.

PREPARATION FOR SURGERY

The obstructed patient shows greater or less dehydration, depending on the level of the lesion. Reasonable evaluation of the degree is possible through hematocrit determinations. Chemical status can best be established by determinations of plasma protein level, plasma chloride level, blood urea nitrogen and carbon dioxide combining power. In general, the patient showing clinical dehydration may be assumed to have lost 5 to 7 per cent of his body weight, and the amount of water administered intravenously in the first twenty-four hours should be about 7 per cent of his body weight. Half of this infusion should be given in the two or three hours before surgery, the rest at a rate not exceeding 400 cc. an hour and preferably spread over the full twenty-four hours, to minimize

$$\frac{560 - \text{Plasma chloride (as mg per 100cc NaCl)}}{200} \times \text{Body weight (kg)}$$

A somewhat smaller amount is usually sufficient. Until the plasma chloride level has been reported, hydration can be nicely initiated by starting intravenous infusion of a mixture of equal parts of 5 per cent dextrose in distilled water and 0.9 per cent sodium chloride solution. In most instances hydration and chlorination can be completed with this mixture.

It is noteworthy that obstructing lesions of the right colon usually produce marked small bowel distention. It is of paramount importance that cases of apparent ileac obstruction be carefully scrutinized to determine whether there is cecal distention, for right colic cases fall even ahead of left colic and strangulating ileac lesions as the most acute and treacherous emergencies in the bowel obstruction field.

signs of strangulation that depletion below 6 gm. per 100 cc should dictate a day or two of delay for replenishment by transfusion. In all other cases, complete obstruction of ileum or colon, the risks of delay vigorous use of plasma

SURGICAL TECHNICS

No attempt will be made here to cover completely the procedures which may be employed. Rather, certain of them will be presented which have proved themselves of particular value in the past few years.

For incarcerated or strangulating hernia repairs in poorly prepared patients, more satisfactory and safe anesthesia may be obtained by novo-

cain block than by either spinal or general methods. In other instances the policy at the University Hospitals has been to use cyclopropane and oxygen administered through a tracheal tube by a closed system machine; supplementation with curare by the intravenous route has simplified matters immensely. Most important, a good anesthetist in attendance widens the range of surgical possibilities.

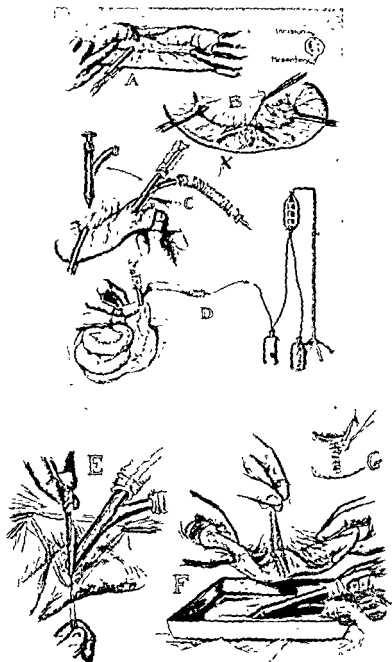
Placement of a No. 17 or No. 15 needle for intravenous infusion into the cubital vein at the elbow offers a large degree of security, especially if cross matched blood is present in the operating room.

Aside from hernioplasties, most emergency operations for intestinal obstruction are exploratory in that the site of the block in the abdomen is unknown. Longitudinal or oblique incisions are, therefore, to be preferred in ileac obstruction, as they provide wider possibilities of extension and exploration. The right midrectus is very satisfactory. Closure of the abdominal wall is most safely made with interrupted fine silk sutures of 3 or 4 pound tensile strength. Most of these patients may then safely be ambulatory the day after surgery, a measure which seems to have simplified the postoperative course immensely. In transverse colostomy a transverse incision is essential to regular success.

Wangensteen nasal suction tubes are placed in the stomach prior to surgery unless the case has been treated conservatively long enough already to have a Wild tube down.¹⁷ Suction is maintained throughout the sojourn in the operating room and postoperatively until sounds are normal and gas is passed by rectum, in the ileac obstructions, or by colostomy in the colic obstructions. This usually occurs two to three days after surgery. Nutrition by the intravenous route is continued in these cases until oral feedings are possible.

Aseptic Decompression.—Wangensteen has described a method of aseptic decompressive enterotomy¹⁸ for dealing with marked ileac distention which permits safe exploration where indicated regardless of that distention. The author has used the method with slight modifications in some two dozen cases, with entire satisfaction as to relief of distention without peritoneal contamination.⁴ In many cases it would have been utterly impossible to deal successfully with the obstructive mechanism if preliminary decompression of the fragile, thin walled bowel had not first been accomplished.

Use of Wangenstein's aseptic suction enterotomy as modified in this series of cases may be performed with the set supplied by V. Mueller and Company or with equipment to be found in any well supplied operating room (Fig. 516). The essentials consist of an ordinary empyema trocar, a soft rubber catheter large enough just to pass through the trocar, a long piece of Penrose drain, connecting tubing, a Wangenstein suction set, and sterile glycerin. Secure ridges for provision of anchorage of the bowel to the trocar may be formed by sliding three 2 or 3 mm. segments of heavy snug-fitting rubber tubing onto the end of the trocar before autoclaving. The heat of sterilizing seals them securely. As indicated in Figure 516, a piece of Penrose drain is tied on the sidearm of the trocar and



covers the entire external length of the catheter, being tied securely over a glass connector in the back end of the catheter. A half ounce of glycerin inside the soft rubber drain serves as lubricant. A second piece of Penrose drain is tied around the handle of the plunger of the trocar to avoid leakage from that source. A long segment of tubing connects the catheter to a Wangenstein suction set. About twelve holes, each 3 mm. in diameter, are cut in the last 6 cm. of the catheter.

In using the apparatus, the most distended free segment is delivered cautiously and milked empty between the second and third fingers of the two hands of the surgeon, and Scudder clamps are very gently applied to keep that segment empty. This maneuver allows contraction of the muscle layers and consequent thickening of the bowel wall so that a firm bite may be obtained for sutures without the danger of leakage through the paper thin walls present before emptying. A purse string of No. 00 catgut on an atraumatic needle is laid, the purse string being 15 to 20 mm. in diameter. A second purse string laid 3 mm. wide of the first is extremely effective in eliminating leakage later. A transverse incision 1 cm. long down to the mucosa is made in the center of the purse strings, and the end of the trocar is secured to the bowel by tight tying of the catgut strands. Greater security is afforded by tying each end over the sidearm of the trocar.

Suction is first applied, and then the plunger of the trocar is used to perforate the mucosa and then drawn back. The catheter can now be inserted into the bowel, and the Scudder clamps removed.

the center exposes the intact mucosa so that easy perforation will be possible with the plunger point.

soft rubber drains, lubricated with glycerin

D, Suction decompression. Very gentle lifting of the segments of bowel will direct content to the catheter. The entire small bowel can be emptied by this means, particularly if a 3 foot catheter is employed.

E, Clean removal of the trocar. A transverse row of interrupted Lambert sutures

bowel.

F, Closure of the defect. Traction on the ends of the preplaced Lambert sutures apposes the edges without suturing.

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It is now practicable to empty the entire small bowel above the site of obstruction by very gentle threading of the catheter through the bowel in both directions and by gentle elevation of the fluid filled loops to lead fluid to the catheter.

Direction of catheter after rather c of the bowel absent or minimal.

In some instances it will be found that strangulation has rendered a segment nonviable. In such cases it simplifies the procedure to have placed the trocar close to this area, enabling the surgeon to resect both the gangrenous bowel and the trocar site in one segment. This is usually accomplished by selection of the most distended loop, usually the lowest one, for decompression.

If simple obstruction is found and relieved without resection, closure of the decompression site must be accomplished. To do this cleanly, an effective procedure is to preplace six to eight Lembert stitches in a transverse row in such fashion that tying after removal of the trocar will invert all the bowel involved in the purse strings and 0.5 cm. more on each side. After preplacement of the sutures, the catheter is withdrawn into the trocar, and the suction left in force. By traction on the catgut ties previously brought over the sidearm, each purse string can be visualized and divided with a No. 11 Bard-Parker knife blade. A discard basin held immediately adjacent to the bowel receives the trocar, and other instruments, with minimal chance for contamination. The Lembert sutures are tied, completing the closure. A second row of closure has been abandoned as unnecessary.

The rather extensive inversion of tissue which occurs does not occlude the lumen because of the marked stretching of the bowel produced by preoperative distention. In no instance has clinical obstruction in the postoperative period been recognized. On a few occasions laparotomy for other lesions at a later time has made possible reexamination of this area. Except for the presence of suture, it is usually very difficult to differentiate this segment from others in the small intestine.

Resection of Gangrenous Bowel.—Experience at the University Hospitals has shown that resection with primary end-to-end anastomosis is a practicable and safe method of dealing with small bowel obstruction in which nonviable intestine is found.⁶ The anastomosis recommended is a modification of that of Martzloff and Burget. One of the chief difficulties which this procedure is designed to overcome is the end-to-end union of segments of widely differing diameter without the formation of blind pockets or kinks.

The mesentery is meticulously cleaned from the distended bowel proximal to the point of large vessels in the crushing, anastomosis mesenteric border, at an angle of about 75 degrees from the long axis of

the gut. The clamp crosses the mesenteric border about 6 mm. below the edge of the unremoved mesentery.

In order to minimize the danger of spillage of any of the content of the distended bowel during the later stages of the procedure, the contents are cautiously milked back between the fingers for 10 or 20 cm. from the

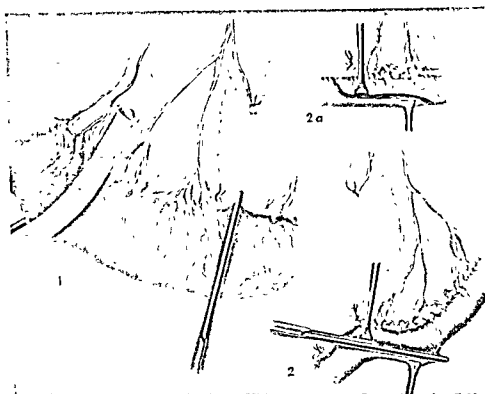


Fig 517.—1, Placement of the first anastomosis clamp on the distended bowel above the point of obstruction. The clamp crosses the bowel at an angle of 75 degrees and at the mesenteric border about 6 mm. from the edge of the unremoved mesentery. The bowel has been milked back and a rubber shod clamp is applied to prevent spillage.

2, Placement of the second anastomosis clamp on the contracted bowel below the point of obstruction. The line of crush begins 6 mm. from the unremoved mesentery, crosses obliquely two-thirds of the bowel and passes for a distance parallel with the antimesenteric border before crossing the remaining one-third of the bowel. *a*, This length of crushed tissue, equal to that in 1, is obtained by distorting the bowel with Allis forceps. This clamp is placed from the mesenteric border.

(From Surgery, Gynecology and Obstetrics, Vol 77.)

clamp, and a rubber shod intestinal clamp is lightly applied. This clamp remains in place until the completion of the anastomosis.

Below the point of obstruction, the diameter of the bowel is usually one-third to one-half that above, and the anastomosis clamp must therefore be placed much more obliquely to attain a length of crushed tissue equal to that above. Most satisfactory stomas have been achieved by the application of the clamp from the mesenteric border with distortion of the bowel by Allis forceps lightly applied in such fashion that the line of

crush, beginning at the mesenteric border, crosses obliquely two-thirds of the way to the antimesenteric border, then runs longitudinally down the bowel to gain the necessary length of crush before it crosses the remainder of the gut (Fig 517, 2, 2a). The cleaning of the mesentery and the placement of the clamp with regard to the cleaned area are accomplished as on the distended intestine *

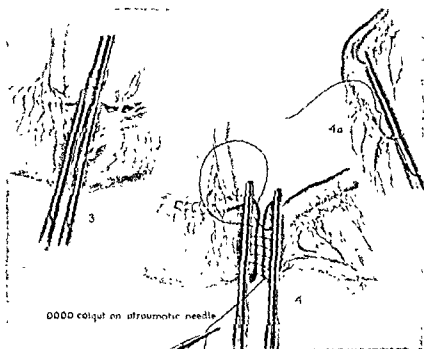


Fig 518—3, Cutting the bowel between the clamps described in Figure 517 with the cautery. To prevent spillage additional clamps are placed between those shown. The specimen to be removed is indicated by the circle.

from each other as shown. The bites are 5 mm. long and the gaps between bites are 4 mm. a, Placement of each end bite parallel with the long axis of the gut assures good inversion later.

(From Surgery, Gynecology and Obstetrics, Vol 77.)

A similar clamp is placed between the bowel to be resected and each of the clamps already described, a 3 or 4 mm gap usually being left be-

between the clamps. The type of placement is not limited to anastomoses performed in difficult conditions the inversion of the lumen has proved uniformly successful under these circumstances. In other sites where bowel ends of unequal diameter are to be joined, such as in end-to-end ileocolostomy after right hemicolectomy, this type of anastomosis has also proved uniformly successful.

tween clamps. The intestine is cut in the gap between each of these pairs of clamps with the actual cautery (Fig. 518, 3).

The anastomosis clamps are laid side by side, thus bringing the bowel ends together with one end rotated 180 degrees with respect to the other about the long axis of the gut (Fig. 518, 4). Ideally the length of the area of crush in the two clamps is identical, for by this precaution the most accurate apposition of the two ends can be attained in making the anastomosis. The clamps are rotated away from each other, and a running bast-

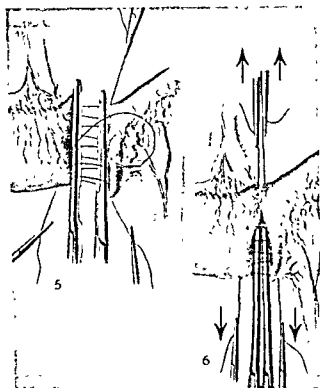


Fig. 519.—5, Placement of the anterior running catgut suture. The clamps have been rolled together.

6, Removal of clamps. Tension is applied to the two ends of each of the running sutures, the clamps are carefully loosened until the tips are spread 1 or 2 mm. and the clamps are cautiously and simultaneously removed.

(From Surgery, Gynecology and Obstetrics, Vol. 77)

ing stitch of No. 00 or No. 000 plain catgut on an atraumatic needle is placed posteriorly, about 5 mm. being taken in each bite, with a slightly smaller gap (4 mm.) being left between bites. Subsequent inversion occurs spontaneously at the time of withdrawal of the clamps only if the ends of the running sutures are properly placed; inversion of the corners with instruments, which invites contamination, may thus be avoided. Each end bite of each suture must be about 5 or 6 mm. long and parallel with the axis of the bowel, and should emerge close to the clamp (Fig. 518, 4a).

The anastomosis clamps are now rolled together, and a similar running stitch is placed anteriorly (Fig. 519, 5).

Tension is applied to the two ends of each of the basting sutures, the clamps are carefully loosened until the tips are spread 1 or 2 mm., and the clamps are cautiously and simultaneously withdrawn (Fig. 519, *c*). If the sutures have been properly placed, inversion of the cut ends of intestine will occur with no further manipulation, and clean serosal approximation will result. Tension is maintained on the basting stitches while the ends of the posterior strand are tied to the corresponding ends of the anterior strand.

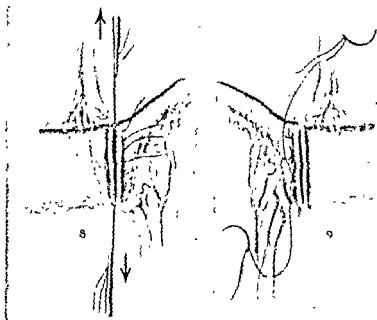


Fig. 520—8, Tying of the Halsted mattress sutures, with maintenance of tension on catgut strands. The posterior side is treated in similar fashion.

9, Rear view of anastomosis, showing placement of stitch to close the mesenteric defect.

(From *Surgery Gynecology and Obstetrics*, Vol. 77.)

With maintenance of tension on the ends of the basting stitches throughout, interrupted Halsted mattress sutures of 25 pound test silk or cotton are laid anteriorly, and the mattress sutures are tied just tightly enough for snug apposition (Fig. 520, 8). The bowel is rolled over, and the posterior closure is similarly reinforced, tension being continued to this point on the ends of the catgut strands. Tension on the basting sutures is gradually lessened as the stoma is broken down by inverting the bowel below the anastomosis with a thumb or two fingers and thus pushing through the stoma. The catgut basting stitch, which is circular by virtue of the knots at the ends of the suture line, is held taut by this device while inversion Halsted mattress sutures are placed at the ends. The

catgut ends are cut just inside the knots on one end and withdrawn altogether. They have served to hold the bowel for placement of the silk sutures, and the removal of them leaves a one layer silk anastomosis, thus free of the delay in mucosal healing resulting from continued presence of the catgut.

To close the mesenteric defect, a stitch near the center of the posterior suture line is threaded on a needle and a small bite of each mesenteric edge is taken 3 cm. from the bowel (Fig. 520, 9), and behind it, and thus the defect in the mesentery is tied. From this point to the root of the

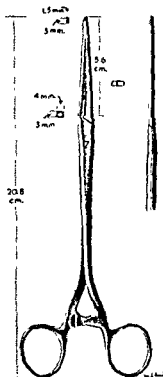


Fig. 521.—The anastomosis clamp 9. (From *Surgery, Gynecology and Obstetrics*, Vol. 77.)

mesentery, interrupted silk sutures are placed. Efforts to cover the suture line with omentum have been abandoned as useless.

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clamp one may rely less on the springiness of the instrument to crush the tissue at the tip, and the clamps may therefore be more easily removed during the anastomosis. Deep, sharp, longitudinal, matching grooves are cut on the jaws of the clamp (Fig. 521).

The advantages of this type of anastomosis over many of those described in the literature are as follows:

1. End-to-end anastomosis avoids the formation of the blind pouches

* Clamps can be obtained from V. Mueller Company, Chicago.

which result from closure of both ends and side-to-side anastomosis (Fig 522).

2. End-to-end anastomosis necessitates but one suture line, whereas closure of the ends and side-to-side anastomosis requires three lines.

3. Aseptic procedure permits apposition of serosal surfaces uncontaminated with luminal contents, a point heavily supported by experimental work

4. Obliquity of placement of clamps permits the best possible blood supply to the line of suture, for the vessels follow a circular course around the bowel and are not, therefore, interfered with before reaching the suture line.

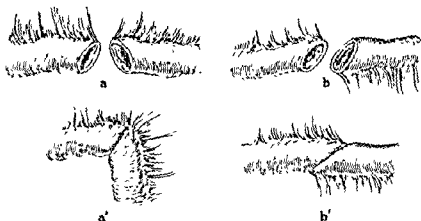


Fig 522 —a, Schematic drawing to illustrate the angulation resulting from end-to-end anastomosis for bowel cut at 45 degrees and apposed without rotation. b, The obviation of angulation accomplished by rotation of one segment with respect to the other is apparent (Reprinted from Surgery, Vol 5)

5. Rotation of one segment of bowel with respect to the other minimizes angulation and therefore minimizes possibility of obstruction at the point of anastomosis, as shown in Figure 522.

6 Rotation of the bowel avoids the dangers of closure without peritoneum at the mesenteric border; in other words, by this rotation peritoneum is provided on one surface or the other completely around the line of inversion.*

7. This type of anastomosis avoids the danger of stenosis at any time in the postoperative period. There has been no case of dysfunction secondary to the quarter twist imposed on each end to be anastomosed.

Use of this or the Martzloff-Burget anastomosis should not be

* In over sixty clinical cases and sixty experimental anastomoses, no instance of leakage at the ends of the suture line, i.e., at the mesenteric border on one side, has occurred. In one case leakage has occurred in the midportion, but here the peritoneum was found contaminated with feces when the abdomen was first opened.

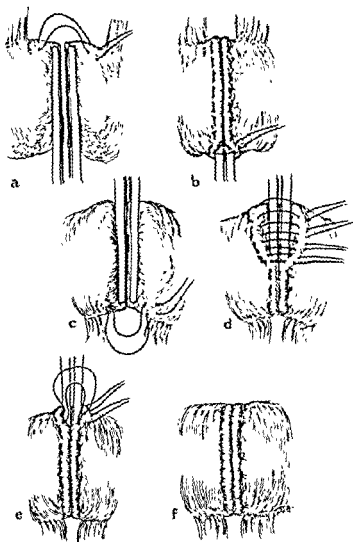


Fig 523.—Closed, one-layer, interrupted silk anastomosis. *a*, Placement of first Halsted mattress sutures. Note that the clamps are placed not quite completely across the bowel. The point of exit of sutures closest to the modified Martzloff clamp is 7 mm. from the cut edge of the bowel. If the bowel is less than 2 cm. in diameter, either smaller clamps may be used, or the sutures may be placed immediately adjacent to the clamps and the clamps removed before tying the stitches, or, preferably, the two layer, oblique, end-to-end anastomosis may be used, best with withdrawal of the inner catgut basting stitch after completion of the silk suture line. When the distance from the cut edge of the bowel to the stitches is more than one-third the length of tissue along the crushing clamps, real danger of obstruction is present. *b*, Completion of back side of anastomosis, tying also over ends of clamps. *c*, and *d*, Front side of anastomosis. *e*, Removal of clamps—delayed until all but two sutures have been tied. *f*, Completion of anastomosis by tying last two sutures after removal of clamps. The total number of sutures for intestinal anastomosis has varied from 11 to 18. (From *Annals of Surgery*, Vol. 123.)

attempted by those unfamiliar with intestinal suture until some experience has been gained in the dog. Difficulties may arise from improper placement of the catgut suture, tearing of the friable distended bowel by

use of heavy instruments or too heavy sutures, and postoperative adhesion formation at the site of placement of the Scudder clamps. There is no need to resect bowel because it is distended or because it fails to contract on stimulation by snapping with the finger, or because it does not offer normal resistance to placing the needle. The greatest gentleness will be rewarded by absence of postoperative cramps or obstruction.

In infants in whom intussusceptions prove irreducible or frankly gangrenous, resection is essential. Gross and Ware have reported a method in which a temporary double barreled ileostomy or ileocolostomy is closed after three to four days.¹² His is an enviable record, and the first to be presented with low mortality. To the author it has seemed more direct and neater to do a primary closed anastomosis. Here both the upper and lower segments are large in diameter, and the anastomosis may be done over narrow anastomosis clamps without the temporary use of catgut (Fig. 523).

Much discussion centers about the choice of closed as against open anastomosis. Where good preparation of the bowel is possible, it does not make much difference which is used. In obstruction cases this is not true, and comparison of open as against closed anastomosis series, both in the laboratory and clinically, shows that the results have been distinctly better where serosal contamination has been minimized by closed anastomosis.⁹

Femoral Hernia with Gangrenous Bowel.¹³—Under local block anesthesia, a vertical incision is made over the bulge in the groin and carried cautiously down to the peritoneal sac. The contents of the sac can be visualized through the remaining wall, bloody fluid, pus, feces, or black bowel can usually be readily recognized (Fig. 524, a).

In case any of these indicates the presence of gangrenous bowel, dissection in this area is discontinued, and an incision is made 2 cm. above the inguinal ligament and parallel to it, and the vertical incision is continued upward to it to make a T-shaped incision (Fig. 524, b). The aponeurosis of the external oblique muscle is split parallel to the ligament and about 1 cm. above it, and extended into the external inguinal ring. The margins of the internal oblique and transversus muscles (and the cord if the patient is male) are elevated, the deep epigastric vessels are divided and ligated, and the peritoneum is incised parallel with the oblique skin incision.

From this vantage point, the viscera entering the hernia may be easily seen. Omentum, if involved, is easily divided and ligated close to the neck. The small bowel entering the sac is prepared by division of the mesenteric attachment from the proximal to the distal side of the incarcerated loop of bowel. Two Ochsner clamps are placed across each of these limbs of bowel, and the ileum is severed between each pair with the cautery.

After the gangrenous sac contents have been freed from intra-abdominal attachments, the inguinal ligament is divided close to the pubic attachment and split laterally, leaving enough heavy aponeurotic tissue

applied to the front of the neck of the sac to prevent relaxation of the neck and release of the soiled content. The sac is encased in a rather firm layer of fascia derived from the femoral canal. Dissection outside it frees the entire sac except for the residual fibrous portions of the ring, which can then be cut under direct vision from the surrounding tissues and left on the neck of the sac (Fig. 525). Palpation for an anomalous obturator artery adds an item of safety here. The entire contaminated area may then be removed intact, without soiling of the remaining field.

Further preparation of the remaining bowel ends may then be done easily, and oblique, aseptic end-to-end anastomosis is performed as for

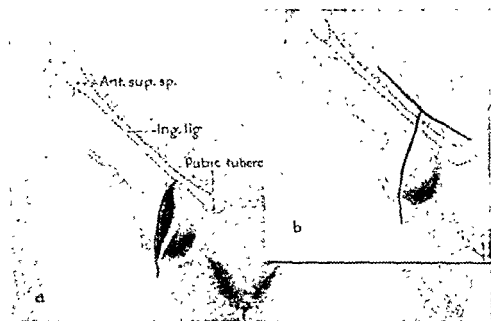


Fig. 524—Femoral hernia with gangrenous bowel. Skin incision *a*, for recognition of gangrene, without opening sac, *b*, completion of incision after recognition of gangrene. (From *Surgery*, Vol. 22.)

any case of resection in the presence of obstruction. Following closure of the mesentery, the bowel is dropped back into the abdomen. Performance of the anastomosis is facilitated by placement of the posterior silk row as interrupted Cushing stitches before use of the running catgut.

Closure of the peritoneal defect in the repair of the hernia is easily accomplished because of the usual mobility of the peritoneum in this area. Closure is usually made by interrupted mattress sutures of 2 pound test silk, approximating the margins of the defect resulting from excision of the sac in a vertical line and closing the original oblique peritoneal incision in a line parallel with the original opening.

Repair of the hernial and surgical defect is simplified by application of the principles of the McVay-Harkins modification of the Lotheisen hernioplasty. The margins of the internal oblique and transverse muscles are sutured to Cooper's ligament as far laterally as the femoral vein and

to the inguinal ligament lateral to that point (the cord in the male ordinarily being left external to this layer). A McVay-Harkins relaxing incision may be made in the posterior layer of the anterior rectus sheath if needed to gain approximation without tension.

The inguinal ligament is restored easily by interrupted sutures of 3 pound test silk, approximating it as far medially as it will go without undue tension, to the lacunar ligament and to Cooper's ligament.

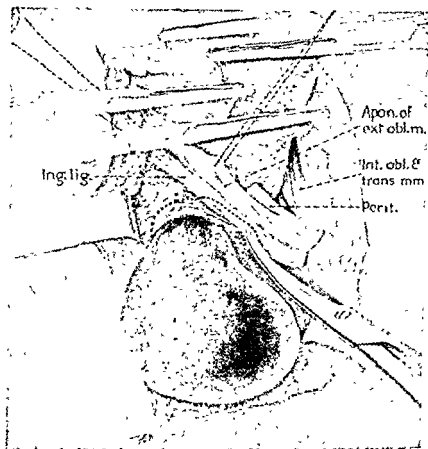


Fig. 525.—Femoral hernia with gangrenous bowel. Separation of neck of sac with retention of intact fibrous ring. (From Surgery, Vol. 22.)

The aponeurosis of the external oblique muscle is finally approximated with interrupted silk (over the cord in the male), completing the hernial repair proper. Silk closure of the skin is used without drainage.

If no evidence of necrosis is apparent upon first exposure of the sac, it is well to dissect the sac rather widely and to place moist packs about it before incision of the sac wall.

In case no nonviable bowel is encountered, the sac, of course, may be widely opened, the hernia reduced by enlarging the neck medially, and the repair done entirely from below.

Transverse Colostomy.—Although the possibility of primary surgery upon obstructing colic lesions appeals to the imagination, experience has shown that the risk is more than twice as great as that of preliminary decompression followed by resection after recovery from distention. These results are considered due to edema and poor circulation in the thinned and stretched bowel wall, combined with actual bacterial invasion from the lumen. Only after these changes have been corrected by recovery after decompression, has surgery to the lesion itself proved feasible. Decompression of the distended colon seen in acute obstruction is to be regarded as a surgical emergency.

Among most surgeons, cecostomy has long been considered the procedure of choice for decompression of the distended colon. Because of the impossibility of really aseptic decompression by cecostomy and the difficulty of complete delivery of the cecum in the presence of marked distention, the mortality is high in that procedure; Wangenstein states that the mortality associated with this operation at the University of Minnesota Hospitals was nearly 50 per cent, a figure corroborated by Campbell² and others.

Several years ago, Wangenstein suggested that decompression in acute left colic obstruction be accomplished by transverse colostomy.¹⁴ He emphasized that the incision could be precisely placed over the distended transverse colon to be exteriorized if a preliminary scout film with a coin on the umbilicus was made (Fig. 526). This is a sound precautionary measure. Wangenstein particularly emphasizes in his teaching at the clinic here that this procedure must be done through a transverse incision, preferably cutting across the right rectus muscle halfway between the umbilicus and the xyphoid. Patients have been referred to this hospital after attempts to accomplish decompression of the transverse colon through vertical abdominal incisions, and this procedure has failed because of inability to deliver the distended transverse colon through such an incision. Decompression of the bowel intraperitoneally in order to facilitate delivery through a vertical incision invites the hazards of cecostomy. Such decompression prior to delivery is almost never necessary after entry through a properly placed transverse incision.

In performing transverse colostomy, the colon is elevated over one or two glass rods and further fixed by fine silk sutures securing the omentum and fatty tags to the peritoneum and rectus sheath (Wangenstein). In the presence of distention, no sutures are placed in the bowel wall proper. Massive petrolatum dressings are placed to cover all the field but a small area of the bowel before insertion of a hypodermic needle for decompression. If the bowel refills quickly, it is aspirated every few hours during the next two days; at that time a 6 cm. longitudinal anterior cut is made with the cautery. The glass rods are removed at ten days. This procedure accomplishes complete deviation of the fecal stream, a matter of some importance in subsequent surgical procedures.

Primary Resection of Right Colic Obstructing Cancers.—In obstructing cancers of the right colon, the problem is simplified because the asep-

tic decompression maneuver may easily be applied at the terminal ileum, with decompression of the colon by passage of the catheter through the ileocecal valve, followed by immediate right hemicolectomy with primary closed ileotransverse colic anastomosis. Such a plan has been used five times without incident, with uniform recovery, and with early dismissal from the hospital. One would expect better long term results because of

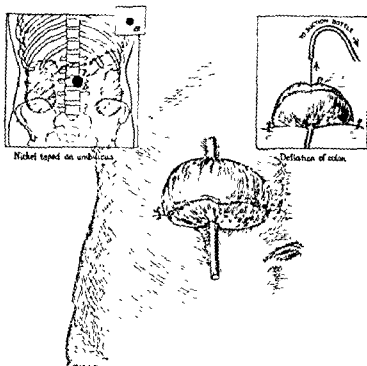


Fig. 526.—Technic of decompressing the distended colon. Sketch of a radiogram from a case. A five-cent piece is taped over the umbilicus. In the insert, on the left, the actual size of the nickel drawn to scale is shown in *a*. The 33 per cent enlargement on the anterior abdominal wall is shown in *b*. The intestinal coils within the abdomen are enlarged 25 per cent. In the insert on the right, the method of deflating the colon on completion of the operation is shown. After a few such aspirations, the bowel is incised and a tube is inserted before it is finally cut for 6 cm. longitudinally. The tension in the bowel is determined before its contents are aspirated. (From Wangenstein, O. H., *Intestinal Obstructions*, Ed. 2, Springfield, Ill., Charles C. Thomas, 1918.)

earlier removal of the offending carcinoma, but no data are available on this point.

Reduction of Volvulus of the Sigmoid Colon.—Dr. Christian Bruusgaard of Ullevaal Hospital, Oslo, Norway, recently spent a year with us at Dr. Waagensteen's clinic. His report of proctoscopic deflation of the distended sigmoid involved in torsion¹ was supplemented by repeated demonstrations of the efficacy and safety of the method.

In patients suffering with volvulus of the sigmoid colon, in whom no evi-

dences of impaired viability are present, insertion of a proctoscope until the spiraling folds of mucosa can be seen (at from 15 to 25 cm.) facilitates the passage of a soft rectal tube into the distended sigmoid loop. The brisk escape of gas and liquid heralds a successful result. As Bruusgaard and Wangenstein demonstrated, elective primary sigmoid resection some two weeks later safely relieves the patient of the high risk of recurrence.

In event of evidences of loss of viability, laparotomy with exteriorization of the sigmoid loop is essential and may be followed by later closure of the resultant double-barrelled colostomy.

CONCLUSION

An absolutely essential factor to the consistently successful management of bowel obstruction is accurate diagnosis. Patients with badly depleted nutritional status may have surgery for acute complete bowel obstruction deferred only if signs indicate the process to be a simple small bowel lesion. Right complete colic obstructions appear to present the most acute surgical emergency in the whole obstruction field, with left colic and strangulating small bowel lesions sharing second place. With the advent of the Wangenstein aseptic decompression technic the era of routine nonoperative management has passed, and the well trained surgeon is safest to explore all cases of bowel obstruction. The small bowel and right colic lesions are best explored through a vertical or oblique incision; in left colic obstructions a right upper transverse incision is recommended for transverse colostomy.

More direct technics have reduced the risks in strangulating hernias, in marked distention, in right colic obstruction, in intussusception, and in volvulus of the sigmoid colon. Despite these technics, progress can be expected only by careful attention to water and salt balance as Collier and his group have stressed, and to the protein metabolism of these usually debilitated patients.

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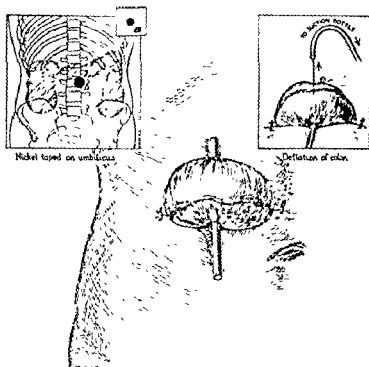


Fig 526 — Technique of decompressing the distended colon. Sketch of a radiogram from a case. A five-cent piece is taped over the umbilicus. In the insert, on the left, the actual size of the nickel drawn to scale is shown in *a*. The 33 per cent enlargement on the anterior abdominal wall is shown in *b*. The intestinal coils within the abdomen are enlarged 25 per cent. In the insert on the right, the method of deflating the colon on completion of the operation is shown. After a few such aspirations, the bowel is incised and a tube is inserted before it is finally cut for 6 cm longitudinally. The tension in the bowel is determined before its contents are aspirated (From Waagensteen, O. H., *Intestinal Obstructions*, Ed. 2, Springfield, Ill., Charles C. Thomas, 1948.)

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MODERN TRENDS IN COLONIC SURGERY

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The surgical management of colon lesions has kept pace with the general advances made in surgery in recent years. Many factors have entered into the situation and it is not proper to stress any single feature in this development. Excellent results are obtained in some clinics without the benefit of some of the newer aids available. It is quite possible that the routine methods we now use are not necessary in every detail in all cases. We feel however that in a teaching clinic, it is better to leave as little to chance or to judgment as we can. The omission of one detail may, on occasion, result in failure. In the formative years of a surgeon, it is well to expose him to carefully planned and accurately executed procedures. His contributions towards improved methods are more apt to be sound and valuable after he has reached some maturity. We do not wish to imply that the following details represent the only satisfactory methods of handling these cases, but we present them as a plan of management that has worked out well in our hands. Our remarks will be confined largely to the treatment of malignant lesions of the colon and we will present the data on such cases operated on by us from 1943 through 1948. Comparison between these and a group of patients treated prior to 1943 will be made.

DIAGNOSIS

Since the operability and often the curability of lesions of the colon depend on early diagnosis, it is important that educational programs be continued along these lines. In an earlier report,¹ we found that the average duration of symptoms in patients with carcinoma of the colon referred to us was seven months. In the present series, the average was 4.5 months. Although this does not seem to have materially influenced the resectability percentage, it may well have a beneficial effect on the cure rate.

The most frequent symptom is *change in bowel habit*. The patient may ignore this but more often the physician fails to interpret this early sign correctly. Distress, awareness of discomfort or actual cramplike pains may bring the patient to the doctor. Blood in the stools nearly

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always alarms the patient and he seeks advice. Quite often, the patient accidentally palpates an abdominal tumefaction and asks to be investigated. There are a few patients who appear in a state of complete obstruction of short duration and do not admit any prodromal symptoms or signs.

A careful *abdominal examination* is the first maneuver indicated. One may feel a tumor but more often not. There may be some distention or tenderness which is usually proximal to the tumor. Increased peristaltic sounds may be audible through the stethoscope. The liver edge may be low and in late cases irregular from metastases.

Rectal examination should be made in a routine manner even though the lesion suspected may be well above the rectum. In the Sims position with the patient straining, lesions quite high in the rectosigmoid region may be brought down against the palpating finger. The patient should then be examined bimanually in lithotomy position, which permits the palpation of sigmoid tumors quite readily and occasionally reveals a mass in the cecum that was not felt while the patient was supine.

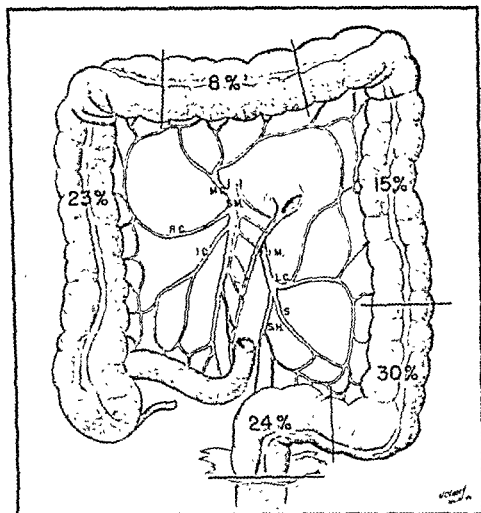
Sigmoidoscopy should be carried out even if the lesion is known to be located well above the range of the instrument. Polyps in the lower bowel are often found and these should be carefully noted for future treatment. Biopsies of many sigmoid tumors are easily made under vision with a long euret. Blood may be seen coming from a lesion well beyond the range of the sigmoidoscope.

Roentgenograms should not be made until all of the above examinations have been done. Too often, the patient is sent directly to the x-ray laboratory for barium enema before any other examination has been made. At times, this may prove disastrous since lesions may not be obstructing in the antiperistaltic direction and the whole colon may be filled with barium above an obstructing lesion. This situation greatly increases the hazard of treatment. A scout film of the abdomen is all that one may need to postulate with reasonable accuracy the location of the lesion. The gas pattern is often observed in the proximal bowel coming to an abrupt end at the site where the obstruction exists. Having done this, one may verify the situation by a carefully given barium enema in close cooperation with the roentgenologist. Fortunately in most of these obstructing lesions, the barium is definitely halted at the site of the tumor. In doubtful lesions shown in the x-ray films, it is imperative to repeat the examination under ideal conditions. Under no circumstances should patients with low abdominal complaint be given a barium meal as the first diagnostic procedure.

LOCATION OF THE LESION

From vital statistics, one is led to believe that there are about twice as many carcinomas of the colon as there are rectal cancers. There is a certain amount of confusion in the minds of many concerning the exact dividing lines in the various segments of the large bowel. These

are not too important provided one does an adequate cancer operation for the lesion that is found. We have chosen to divide the colon in segments depending on the blood supply. This is outlined in such a



INCIDENCE OF CANCER OF COLON 1943-1948

Fig. 527 —The sigmoid colon, representing 54 per cent of the resections, has been diagrammatically divided to show the area of the resection in which it was necessary to mobilize the pelvic peritoneal reflection (24 per cent) and that in which this procedure was not necessary. Actually, in most low resections the

hemorrhoidal,

manner that removal of the first and main lymphatic spread can be accomplished (see Fig. 527).

The right colon including the cecum and hepatic flexure grouped as one segment was the site of 23 per cent of the cases in this series. The midtransverse colon was involved in 8 per cent; the splenic flexure and descending colon in 15 per cent, and the sigmoid in 54 per cent

(Fig. 527). There are a few instances of lesions in the rectosigmoid or actually in the upper rectum that may be included in the sigmoid group because they were treated in the same manner, i.e., by resection and anastomosis.

PREPARATION OF THE PATIENT

The proper preparation for operation of patients with carcinoma of the colon is influenced by the degree of obstruction present. In *completely obstructive lesions*, the first concern is immediate proximal de-

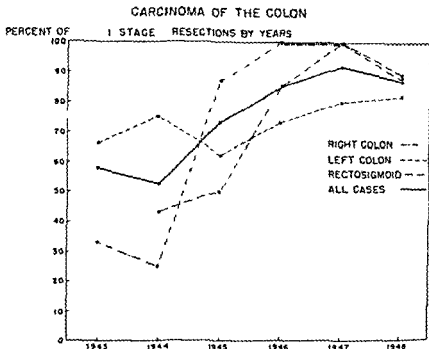


Fig 528

compression. This can rarely be done with the Miller-Abbott or Harris tube, but such a tube should be started even if the gas pattern does not indicate small bowel distention. Blood transfusions and intravenous fluids should be given in adequate amounts immediately.

Completely obstructing tumors of the right colon are less common than those of the left colon. When they do occur, a preliminary ileotransverse colostomy is indicated. In the midtransverse and sigmoid colons, obstruction may be best treated by cecostomy. Transverse colostomy is preferable for left colon obstruction when this can be safely done. At times, this procedure may be carried out a few days after cecostomy in very ill patients in the late stages of obstruction. Rarely, if ever, is one justified in a direct attack on the obstructing lesion as a primary procedure. The few days' delay in the preparation of the patient and

his colon is well worth while and is gratifyingly reflected in the operative mortality. In this series 27 per cent of the whole had some type of preliminary surgical proximal decompression (Fig. 528).

In the majority of patients seen by us, obstruction is not complete and, in fact, many of them have no obstructive symptoms at all. In those with sufficient obstruction to allow an abnormal amount of fecal material to have accumulated in the bowel, attempts should be made to eliminate this material. Saline cathartics, such as magnesium sulfate, usually are effective. Such measures, however, should never be used when the scout film shows marked gaseous distention of the proximal colon. In most instances there is little evidence that the tumor has caused any obstruction and these can best be treated without cathartics. We have found sulfathalidine, 8 gm. daily for five days, an effective drug to cleanse the bowel and our results would strongly suggest that virulent organisms were markedly reduced by its use. We have used streptomycin by mouth, 1 gm. twice daily for forty-eight hours, instead of or in addition to sulfathalidine with good results.

During these days of bowel preparation, the patient is brought to a normal balance in hemoglobin, fluids and electrolytes. His prothrombin time is determined preoperatively. He is kept at rest in the hospital but not in bed save for about half his waking hours. He is encouraged to walk when out of bed. An optimistic attitude is maintained with reassurance that he will survive his operation. We feel that from five to seven days' preparation is indicated for the average patient.

ANESTHESIA

The surgeon may choose the anesthetic best and most satisfactorily administered in his clinic. If spinal anesthesia is used, it is often worth while to add a small amount of nitrous oxide and oxygen or pentothal sodium. There are many advantages to spinal anesthesia from the standpoint of muscle relaxation and the decreased need for manipulation of the small intestine. The occasional unsatisfactory anesthesia and the rare serious meningeal or peripheral nerve irritation dampen one's ardor for the method. Cyclopropane with intermittent doses of curare appears to be satisfactory in the hands of some anesthetists. Dependence on pentothal sodium and curare alone seems open to question in these comparatively lengthy procedures. An expertly administered gas-oxygen-ether mixture in a closed machine has found more favor with us in recent years than any of the other methods that we have tried. It is necessary to have the patient comfortable and to maintain his blood pressure during the procedure. At times, small doses of neosynephrin may be used to advantage. Every anesthetist should be adequately trained in bronchoscopy, since the aspiration of bronchial secretions may, on occasion, save a life and often spectacularly relieve cyanosis.

INCISIONS

There may be little need for a paragraph on incisions in a report such as this. Perhaps it would suffice to say that adequate exposure of the region is necessary. It must be borne in mind, however, that these wounds need proper closure, and that cut nerves, poorly planned incisions and wound infection may result in dehiscence and ultimate hernia in scar. We most often use long paramedian incisions, retracting the rectus muscle laterally. Oblique wounds are entirely satisfactory for the usual sigmoid resections. Transverse incisions are adequate for the transverse colon. A combination of transverse and oblique incision

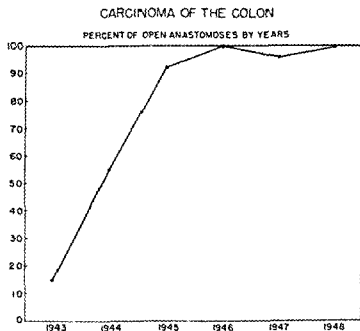


Fig. 529

is useful at times, particularly for small lesions of the splenic flexure. One must not lose sight of the possibility of having to release the attachments of the splenic flexure in a considerable number of left colon tumors, since the nodal spread may make it necessary to remove a very long proximal segment.

TYPES OF OPERATION

It must be said that many experienced surgeons have had such excellent results from some variety of exteriorization (Mikulicz) operation that it would be entirely out of place to criticize the method. We believe that the obstructive resection of Rankin is the best of these procedures and is more universally practiced than any other. One must take into

account the time required for closure of the double-barrelled colostomy. In the pre-antibiotic days, this was a small price to pay for the added safety.

We have always used end-to-end anastomosis following resection for cancer of the colon. In our earlier reports, we stressed the importance and added safety of so-called aseptic anastomoses. The basting stitch technic modified after Parker and Kerr was satisfactory in our hands and we still use it if the bowel has been improperly prepared. Our most common use of it now is in the preliminary ileotransverse colostomy in obstructing carcinomas of the right colon. We have become increasingly more confident in a properly executed open anastomosis in a well prepared bowel (see Fig 529).

TABLE 1

PORTIONS OF CONTACT ORGANS RESECTED IN PRIMARY CARCINOMA OF THE COLON
1943-1948 150 Cases

Uterus and adnexa	13
Small bowel	9
Abdominal wall	9
Bladder	5
Stomach	2
Duodenum	2
Spleen	2
Gallbladder, liver, kidney, seminal vesicles, pancreas, diaphragm, each 1 . . .	6
	<hr/> 48

OPERATIVE TECHNIC

Whatever method of attack one may favor for lesions of the colon, it is imperative that certain basic principles be kept in mind. Our first consideration is the life of the patient. This is so closely related to our desire to cure him of his disease that we may become confused in the issue. Too often however, lesions with contact disease in other structures or fixation may deter the surgeon from a radical effort (Table 1). We believe that one should resect all gross disease including lymph nodes whenever possible. Resection of the primary tumor, with its nodal spread, is justifiable even in the presence of liver metastases. Life expectancy is much greater when liver involvement is secondary to cancer of the bowel than it is when such invasion is associated with cancer of the stomach or pancreas. There can be no question that resection of an obstructing lesion of the bowel is the best method of treating the obstruction regardless of the extent of the process. Simple resection of the primary tumor without regard for the nodal spread is unjustifiable.

A successful extirpation of the disease must include a sufficient segment of normal bowel above and below the growth to include the mesentery and nodes to the limits of the blood vessels supplying that general region. In our schematic diagram of the five segments that we have

used to group the lesions we have treated, it is obvious that there must be some overlapping. Thus, it may be necessary, on occasion, to include two or even three of these segments in an effort to remove all involved nodes. Occasionally such extensions may be necessary because of multiple tumors. The chief factor to keep in mind is that all of the diseased portion must be removed if such a procedure is compatible with life (Fig 530)

EXTENT OF RESECTION IN CANCER OF COLON

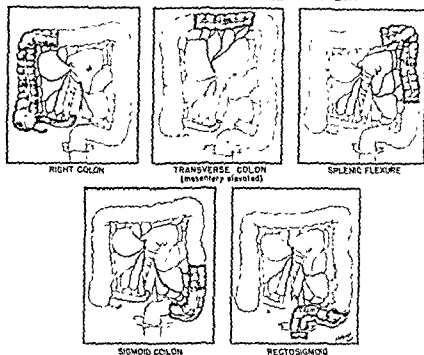


Fig. 530 —The above figures indicate in each instance the actual average length of bowel in each segmental resection as measured by the pathologist. Again, the sigmoid colon is diagrammatically divided by those low resections requiring mobilization of the pelvic peritoneal reflexion. In most of these resections, the proximal dissection was more extensive and included the sigmoidal vessels.

Anastomosis.—Having extirpated the disease, one must then take into consideration the restitution of bowel continuity. A successful anastomosis depends upon several factors. These are adequate blood supply, accurate suture and lack of tension at the suture line. Closely following these in importance are minimal contamination and the closure of mesenteric traps. It has been our experience that in the majority of colon resections, one can approach the nodal area more effectively if the bowel is transected between thin bladed clamps with the cautery early after lateral mobilization has been achieved. Usually this early transection is through the proximal segment; the distal segment is

transected after the dissection of nodal areas, blood supply and mesentery is complete. Rarely have we found that complete mobilization with excision of the entire specimen at one time is attended with as much satisfaction as the method described above. Mobilization and transection of the most accessible end of any portion of the gastro-intestinal tract early in the procedure makes the dissection of the more adherent region much easier.

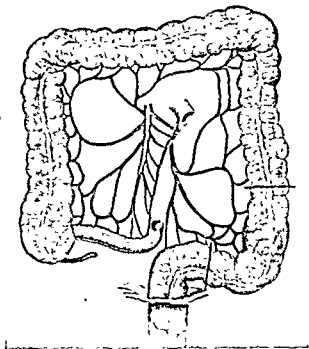


Fig. 531 —Area of resection in open end-to-end anastomosis.

Having removed an adequate segment of normal bowel on both sides of the tumor with the entire blood and lymph supply to the region (Fig. 531), one then proceeds with the anastomosis. In most instances, it is possible to see pulsating blood vessels along the margin of the ends of bowel to be approximated. At times, however, one must rely on the appearance and color of the tissues. If there is doubt concerning viability, it is best to resect at a higher level or exteriorize the bowel ends. We have felt that removal of fat tabs near the suture line was hazardous and should not be attempted. To be sure, this maneuver can be meticulously accomplished in such a manner that the bowel ends appeared to be still viable. Such a procedure is time consuming and dangerous in the hands of the average surgeon and is entirely unnecessary. Sutures can be placed in proper position with almost complete disregard of the fatty structures on the surface of the bowel. These fat tabs carry terminal vessels that play a role in the proper nourishment of bowel wall. Those that may be occluded by the suture are unimportant in the healing

process. Leakage at the suture line will occur less often if these fatty structures are included in the sutures than if they are first removed.

Suture (Fig. 532) —We place a posterior row of interrupted No. 30 cotton sutures close enough together so that an average of twelve of these are used. These sutures are tied before the clamps are removed, if possible, and we estimate that they will rest about $\frac{1}{4}$ inch (5 mm.) from the cauterized, crushed end of the bowel. After a second walling off procedure, the clamps are removed one at a time. Usually the distal clamp is removed first and the seared edges of the bowel gently separated. With the suction tip ready but seldom used, any fecal material near the site of suture is gently removed with small, moist pledgets of gauze. Then the proximal clamp is removed. In a well prepared bowel, there is rarely much gas or fecal matter that cannot be completely controlled by small gauze wipes. Occasionally the suction tip is needed on the proximal end.

A posterior continuous row of fine chromic gut on a small atraumatic needle is then introduced, great care being taken to draw the suture firmly but without tension, an over-and-over stitch is probably better than one that is locked. The usual size of catgut used is No. 3 zero. This accurate approximation of the mucosal edges is for hemostasis mainly but does give the bowel a few days to adhere over the moderately broad serosal surface between the two suture lines. Although there may be a slightly constricting action of the continuous catgut suture line, we feel that this is temporary and that the final stoma will be as large as the normal bowel caliber. The anterior row of catgut is put in after the method of Connell as close to the cut edge of the bowel as is feasible to insure inversion of the mucosa into the lumen.

The anterior row of interrupted No. 30 cotton sutures is then made. These may be tied as they are inserted but usually are best tied after all are in place. The posterior row of cotton sutures is placed transversely in a mattress pattern because one cannot be sure of the location of tiny blood vessels that should be included in such a suture. The anterior row is usually a vertical mattress pattern except at the white lines where it must be transverse. Too little stress has been placed on the lack of transverse fibers in these longitudinal white lines. Sutures placed in the direction of the lines are very apt to cut through. It is for this reason that incision into the bowel for the removal of a polyp is best accomplished through the bowel wall between the white lines.

At this stage of the operation, the drapes about the suture line and all instruments and gloves used in the anastomosis are discarded. With fresh equipment, the mesenteric trap is closed with a fine catgut suture. This is particularly important on the surface exposed to the small intestine. There have been instances of such wide resection of bowel and mesentery that this detail had to be omitted. It is far better to leave a huge defect in the mesentery than a small one. It is a good general principle to remember that the small intestine has a great affinity for any raw or traumatized surface, particularly the fatty edges.

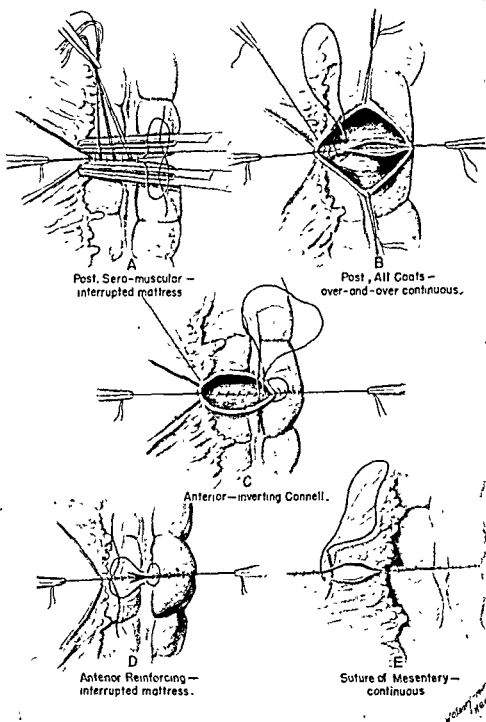


Fig 532.—Technic of open end-to-end anastomosis. In succession are shown: the placing of the posterior serosal layer of interrupted No. 30 cotton, the posterior inner suture of running fine catgut, the anterior inner Connell suture of catgut, and the anterior serosal layer of interrupted cotton. The mesenteric defect is closed with running catgut

of the cut or injured mesentery. If care is exercised in this regard post-operatively, early or late small bowel obstruction will be rare. If there

are unperitonealized areas in the gutters or the pelvis or if there has been any known contamination during the operation, 1 gm. of streptomycin is introduced into the peritoneal cavity. One should view the use of antibiotics as an additional safeguard and not in any sense as a substitute for the most meticulous technic within the range of one's ability.

WOUND CLOSURE

The closure of abdominal wounds is too often carelessly done. If the incision has been properly made and if the wound is adequately sutured, dehiscence should never occur. Layer closure is certainly superior to mass closure. One must take into consideration the amount and type of foreign material used, and dead spaces must be eliminated. The most annoying dead space is in the subcutaneous fat. Fatty tissue tolerates infection less well and heals with greater reluctance than any other structure.

It is now generally conceded that catgut causes greater reaction in the tissues and thereby creates the greatest hazard to healing of any of the suture materials. Fine wire of stainless steel, cotton and silk appears to cause the least tissue reaction in the order named. Wire in the fascia introduced in the far and near pulley-stitch manner as advocated by Jones² has been widely adopted. Certainly this method of closure is excellent and probably the best yet devised in the wound closure about a colostomy. Coller³ uses, in addition, three longitudinal subcutaneous wire sutures to close the fat and skin with excellent results.

We have found that a continuous zero chromic catgut suture closes the peritoneum adequately. The fascia is approximated with closely spaced (4 mm.) interrupted No. 30 cotton. Through the skin, fat, and anterior fascia, sutures of heavy cotton are placed 1.5 cm. apart. These are usually tied forty-eight hours later, after a modification of a delayed closure technic revised by Coller and Valk.⁴ Stay sutures for primary closure are best of medium-sized stainless steel wire. For delayed closure, the wire does not lend itself to manipulation quite so well as does heavy cotton or silk. The invariable mild infection about these stay sutures, if left a long time, has not proved hazardous as far as the character of the wound is concerned. There has been no instance of wound dehiscence and there have resulted only one case of major and two of minor wound infections in the six year period covered in this report.

AFTER-CARE

We routinely use a combination of penicillin and streptomycin intramuscularly for a few days after these operations. 100,000 units of penicillin mixed with 0.25 gm. streptomycin can be conveniently given in the same syringe every three hours. Although infection of the wound or the peritoneal cavity is now rare, we are justified in using these antibiotics to reduce the incidence of cystitis and pneumonitis. It is important to omit antibiotics for several days before the patient is

discharged, thus avoiding serious delayed infection that may be masked by these drugs. Small doses of pantopon or morphine are given often, not only for the patient's comfort but to prevent distention of the small intestine until normal tone has been regained. We have not found that demerol or methadon is quite as effective as the older drugs, particularly

TABLE 2
CARCINOMA OF THE COLON

Years	No. of Cases	Resectability, per cent	Resection Mortal- ity, per cent
1925-1942	143	91	17.5
1943-1948	157	96	2.7

TABLE 3
CARCINOMA OF THE COLON
1943-1948

Resections	No of Cases	Deaths	Mor- tality, per cent
For cure	131	1	0.76
Palliative	19	3	15.8
Nonresectable	7	2	28.6

TABLE 4
AVERAGE HOSPITALIZATION RESECTION OF COLON 1943-1948

	Preop. Days	Postop Days	Total Days
One-stage operation	5.7	18 0	23 7
Multiple-stage operation:			
Preliminary cecostomy	3.0	29 0	32 0
Preliminary ileotransverse colostomy	4.8	32.6	37.4
Preliminary transverse colostomy.	6.3	47.4	53.7

in the immediate forty-eight hour postoperative period. Blood lost at operation is replaced during the procedure or immediately thereafter. Gastric suction is maintained routinely for forty-eight hours. If a long tube has been previously introduced, this is kept on low pressure suction. The patient is allowed small amounts of water by mouth; although this is recovered through the suction tube, it has a good effect on morale and decreases the tube irritation in the pharynx and esophagus. Intravenous fluids are given in amounts needed to hydrate the patient. The average individual will receive about 500 cc. of physiologic saline and 2000 cc. of 5 per cent glucose and water in each twenty-four hour period until adequate mouth intake is feasible. This varies according to the patient and extent of the operation from two to five days.

and in the number of platelets; this increase in the cellular components of the blood lasts only a short time, usually a few weeks.

The spleen exerts a definite role in the fragility of the erythrocytes, although the mechanism of this function is not understood. Erythrocytes and iron may be stored in the spleen.

Abnormal Functions.—The abnormal functions of the spleen are actually more important to the surgeon than the normal, as is shown by the fact that a person can do without his spleen, but if abnormal functions develop, he may acquire very serious symptoms threatening life. Most of these abnormal functions are related to the increase of some normal function. The decrease in blood platelets, encountered as one of the most important manifestations of thrombocytopenic purpura, is due to a hypersplenism inhibiting formation of platelets from megakaryocytes and/or their release into the blood stream. In hemolytic anemia the hypersplenism affects only the function producing an increased destruction of erythrocytes, part of which is related to increase in fragility. If the hypersplenism affects only the function of the bone marrow giving rise to formation of leukocytes, we have a condition known as splenic neutropenia. If all three functions are involved, so that the patient has a low leukocyte count, a low erythrocyte count and a decrease in the number of platelets, we have a condition known as panhematocytopenia.¹

INDICATIONS AND RESULTS OF SPLENECTOMY

Thrombocytopenic Purpura.—The classical manifestations of this disease are prolongation of the bleeding time, normal coagulation of blood, absence of clot retraction, low platelet count, anemia, ecchymosis, petechiae and bleeding from body orifices or mucous membranes. However, it is essential to distinguish between primary (Werlhof's) and secondary or symptomatic purpura, the latter of which may be caused by drugs, allergy, leukemia, infections, aplastic anemia, x-ray radiation and other factors.

The bone marrow examination is diagnostic insofar as a marked increase in the number of immature megakaryocytes is present, although the number of platelets in the blood stream is markedly reduced. The number of megakaryocytes in the bone marrow is an accurate indication of the presence of a true thrombocytopenic purpura and is likewise a fairly good index of the prognosis following splenectomy for purpura. In secondary purpura the number of megakaryocytes is less likely to be increased in the bone marrow. If eosinophils are found in great number, an allergic type of thrombocytopenia may be suspected.

The response to splenectomy is usually immediate and in almost all instances remarkably effective. However, on some occasions the beneficial effects are small or ineffective. In our series of splenectomies we had twenty-six patients with thrombocytopenic purpura for which the operation was performed; there were no operative deaths in this

group. The results were classified as good to excellent in twenty-three of the twenty-six cases. One other patient had relief from purpura but died two years later from pulmonary tuberculosis. Two of the three patients not listed as having good results had good symptomatic results but poor hematologic results.

At operation the surgeon should always search the hilus and adjacent tissue for accessory spleens since recurrence or actual persistence of symptoms may be produced by an accessory spleen.

Acute Hemolytic Anemia.—Although this disease is congenital or familial in origin, symptoms are frequently not noted until adult life. There are usually several members of the family afflicted with the disease although in some cases the symptoms are extremely mild, perhaps revealing nothing subjectively or objectively except slight jaundice and enlargement of the spleen. The classical manifestations of splenomegaly are jaundice, anemia, microspherocytosis and increased fragility of the red blood cells when placed in hypotonic salt solution. Reticulocytosis and urobilinuria are usually present. The splenomegaly is frequently very marked, the bone marrow reveals hyperplasia of the myeloid, erythroid and megakaryocytic elements, although these findings are by no means diagnostic.

It is essential to separate congenital hemolytic anemia from acquired hemolytic anemia in which the etiology may be unknown. Important causes of acquired hemolytic anemia are certain chemicals such as benzol, infections, and parasites; malignant diseases such as leukemia or other conditions in which abnormal hemolysins and agglutinins are found may also give rise to acquired hemolytic anemia. Other factors occasionally giving rise to hemolytic anemias of the acquired type are Hodgkin's disease, agnogenic myeloid metaplasia of the spleen, lymphosarcoma, carcinomatosis, severe liver damage and dermoid cyst of the ovary. In some patients with acquired hemolytic anemia, spherocytic erythrocytes may be found, although their absence is frequently an indication of the presence of acquired hemolytic anemia rather than the congenital type in which spherocytosis is practically universal. On some occasions splenectomy will relieve the manifestations of acquired hemolytic anemia, but obviously will not affect the underlying primary condition, such as leukemia or Hodgkin's disease.

In hemolytic anemia, transfusions commonly give rise to serious reactions. Of recent years there has developed an agreement that such patients should not have transfusion before operation lest the patient develop an acute hemolytic reaction which might be fatal. Accordingly, numerous donors are made available but no blood is given until the splenic artery is tied at the operation.

In our series we performed splenectomy on twenty-eight patients with hemolytic anemia. In this group twenty-three were classified as congenital or familial, and the results of operation were very good. However, in five patients which we classified as having acquired hemoly-

tic anemia, the results were poor. One patient died a few days after operation.

Banti's Disease.—We have learned only recently that splenectomy for Banti's disease should be performed only in early cases and not in late cases. The mortality rate is so high in the latter group as to be prohibitive. The cardinal manifestations of so-called Banti's disease are splenomegaly, anemia and leukopenia. Jaundice and ascites develop relatively late. Adhesions develop relatively early between the spleen and adjacent tissues, including the abdominal wall. If portal hypertension is significant these adhesions become very vascular, offering an outlet for the portal blood which is blocked by obstruction in the portal and splenic vein or by cirrhotic changes in the liver.

Bone marrow findings will vary depending to a great extent upon the stage of the disease. Early in the disease there is a myeloid hyperplasia (maturation arrest) as well as a moderate anemia and leukopenia in the peripheral blood.²

In our series of thirteen patients classified as Banti's disease we had five postoperative deaths. It is the experience of almost all surgeons that most of the operative fatalities following splenectomy occur in Banti's disease. Part of the explanation lies in the fact that in this syndrome portal hypertension is present and the danger of postoperative hemorrhage is increased tremendously. In confirmation of this point four of our five patients died from hemorrhage; at least hemorrhage was a factor in the patient's demise. One patient died two years after splenectomy and the other eighteen months after splenectomy. We were unable to follow two others. In only two of the eleven patients followed can we say that the results were good. This indicates very clearly that splenectomy for Banti's disease is a poor procedure, although it is agreed that in early Banti's disease splenectomy may exert a very beneficial role.

It should be emphasized that splenectomy alone for portal hypertension of the Banti's type cannot be considered a very logical operation unless hypersplenism is present to a significant degree. Even if hypersplenism is present, there is a strong possibility that splenectomy will not relieve hemorrhage from esophageal varices when present. For example, in a series of twelve patients with hemorrhage due to portal hypertension, Lahey and Norcross³ reported a recurrence of bleeding in three patients.

The question of postoperative hemorrhage in portal hypertension obviously brings up the question of the advisability of portacaval or splenorenal shunt. At the time of operation it is usually possible to determine with a fair degree of accuracy whether or not portacaval or splenorenal shunt is indicated. If the pressure in the coronary vein is elevated (as determined by manometer readings), indicating that the vein empties into the portal system distal to the point of obstruction, splenectomy is not apt to relieve the hemorrhage as a permanent measure. The question as to the type of shunt to be performed is entirely

a matter of controversy. Linton and associates⁴ favor splenorenal shunt. However, Blakemore⁵ and others favor the portacaval shunt on the basis that a larger shunt can be obtained. The author is inclined to agree with Blakemore that the portacaval shunt is preferable, but is now convinced that it cannot be done in a poor risk patient and must be accomplished without obstructing the blood flow in the portal vein or vena cava. It is now possible to make such an anastomosis with maintenance of blood flow by the use of the Smith-Freeman clamp or a modification of it.⁶

Thrombosis or Anomalous Obstruction of the Splenic Vein.—Most authorities group these patients together with the patients in the Banti's syndrome group. Portal hypertension is a prominent feature in both lesions. I have chosen to separate the group as indicated because in my opinion the prognosis in this latter group is especially good following splenectomy. Not only does splenectomy relieve the hemorrhage from the esophageal varices but it obliterates any progressive damage in the liver. In our series we have five patients whom we designated as having splenic vein obstruction. In our opinion the obstruction was probably produced by a thrombosis but congenital anomalies could not be ruled out. All five of our patients in this group had hemorrhage before operation. Four of the five patients have had an excellent result with no postoperative hemorrhage. One patient listed as fair to good result had two attacks of hemorrhage, shortly after the operation, but has not had any attacks for the past two to three years. In spite of the fact that the hemorrhage failed to recur, the varices are still visible by roentgenologic examination with barium in all cases.

Felty's Disease.—There is considerable controversy as to whether this disease should be identified as a separate entity. The cardinal manifestations are chronic deforming arthritis, painful joints, anemia, splenomegaly, leukopenia, occasionally low platelet count and cutaneous pigmentation with lymphadenopathy. In reality the disease is a secondary splenic panhematocytopenia. We had five patients classified in this group. None of them died in the hospital following operation, although one died two years after splenectomy with a malignant tumor of the thymus. Although postoperative results are fairly good from the standpoint of most manifestations, there is very little improvement in the arthritis in our patients.

Splenic Neutropenia.—This is a relatively new condition described recently by Wiseman and Doan.⁷ Cardinal manifestations are splenomegaly and peripheral neutropenia. Presumably the disease represents a selective form of hypersplenism in which the splenic hormones exert an inhibiting effect on the maturation and delivery of granulocytes from the bone marrow to the blood as neutrophils. The bone marrow usually reveals a myeloid hyperplasia which should be present before splenectomy is justified. The author has had no experience with this disease, but reports indicate that splenectomy is very effective.

Splenic Panhematocytopenia.—Although panhematocytopenia is very

common as a secondary manifestation, the primary type is quite uncommon. The secondary type is seen in numerous conditions, including Felty's disease, Hodgkin's disease, Gaucher's disease and drug sensitization. As indicated previously, the disease represents a type of hypersplenism in which the splenic hormonal function is increased, thus resulting in an inhibition of bone marrow function. The most common manifestations are neutropenia, anemia, and decrease in the platelet count. Anemia may be due to delay in formation of erythrocytes or to the hemorrhagic process. Accordingly the disease represents a combination of hemolytic anemia, purpura and neutropenia. Bone marrow smears reveal hyperplasia of all marrow elements, with a predominance of normoblasts. Without these findings splenectomy is rarely advisable.

We have had no patients diagnosed as primary splenic hematocytopenia but have had secondary cases similar to those described under Felty's disease.

Miscellaneous Diseases for which Splenectomy May Be Indicated.—*Cysts and primary tumors* may be a justifiable indication for splenectomy. *Abscess* may likewise be an indication but is quite rare and difficult to diagnose. Splenectomy may be indicated in *Gaucher's disease* but usually only when some type of panhematocytopenia is present. Cardinal symptoms of this disease are splenomegaly, anemia and pigmentation of the skin. Occasionally there is indication for removal of a spleen enlarged because of *chronic malaria*, particularly if one or more types of panhematocytopenia are present.

We have performed splenectomy in ten patients with miscellaneous diseases, some of which had doubtful indications. Splenectomy was performed in one patient with cyst of the spleen and in one with an aneurysm of the splenic artery, each had an excellent result. We also performed splenectomy on one patient with Gaucher's disease and one with Hodgkin's disease with improvement in symptoms (e.g., anemia) but the ultimate result will of course not be influenced by the operation. One patient with sickle cell anemia, another with atypical hemolytic anemia were not improved after splenectomy. One patient with atypical aplastic anemia died on the eleventh postoperative day of cerebral hemorrhage.

CONTRAINDICATIONS TO SPLENECTOMY

Largely through trial and error splenectomy has been performed during many years past for numerous diseases which revealed splenomegaly or produced other symptoms related to splenic influence. It is now clearly shown that splenectomy is contraindicated in *pernicious anemia*, *leukemia*, *polycythemia*, *agnogenic myeloid metaplasia*, *acute splenic tumor* and most types of *parasitic disease*. Occasionally splenectomy may be indicated in Hodgkin's disease and malaria when hypersplenism is present.

IMPORTANT POINTS IN THE TECHNIC OF SPLENECTOMY

Although a detailed discussion of operative technic is not indicated in this presentation, certain points will be discussed. Details of splenectomy have been presented elsewhere by the author in this journal.⁸ The type of incision is fairly important since good exposure is necessary to eliminate operative complications in a certain group of patients where the procedure is difficult. I have long since given up the paramedian incision since it does not allow good exposure. The Singleton⁹ incision, which is an oblique transverse incision starting in the midpeigastric line half-way between the ensiform and umbilicus, does not allow exposure high up under the diaphragm where gastrosplenic vessels are sometimes numerous and large. We have found that an incision starting as a left paramedian at the ensiform going downward for about 2 inches and curving to the right, cutting all muscles for a distance of about 2½ inches from the lateral edge of the rectus offers very good exposure under the diaphragm and in the lateral splenic gutter. Most of the transverse incisions for splenectomy are apt to sacrifice the eleventh spinal nerve. The twelfth will be seen at the end of the incision and must be spared and retracted.

We have found it very helpful to ligate the splenic artery before any attempt is made to mobilize the spleen, particularly when the spleen is considerably enlarged. The larger the spleen the larger will be the artery, and in fact the more tortuous and accessible it will be. The artery is readily found by making a small incision in the posterior peritoneum at the superior border of the pancreas about 2 inches from the hilus of the spleen. Primary ligation of this artery allows blood to flow out gradually from the spleen, thus resulting in an autogenous transfusion. Moreover, it relieves the vascular tension in the spleen so that adhesions are less vascular and any tears produced in the spleen are less apt to bleed profusely.

MORTALITY RATE

Although we had seven postoperative deaths in our series of eighty-seven patients for which splenectomy was performed in a twelve year period, this figure cannot be used as an index of expected mortality rate in all diseases for which splenectomy is performed or indicated. For example, in twenty-six patients with thrombocytopenic purpura we had no postoperative deaths and in twenty-eight patients with hemolytic anemia only one death (see Table 1). On the contrary, we had five postoperative deaths in eleven patients with Banti's disease (exclusive of patients with obstruction of the splenic vein). With the aid of present knowledge, we can now say that in diseases such as thrombocytopenic purpura and hemolytic anemia splenectomy can be performed with a postoperative mortality rate of less than 2 per cent. In Banti's disease, the rate will be much higher; the actual rate will

depend upon how often splenectomy is performed for the advanced cases. The author strongly advises that splenectomy not be performed

TABLE 1
RESULTS FOLLOWING SPLENECTOMY
(Illinois Research Hospital 1936-1948)

Disease	No. of Cases	Operative Deaths	Per cent Good or Excellent Results	Remarks
Thrombocytopenic purpura	26	0	92	Two had good symptomatic but poor hematologic results, one had good results but died 2 years later of tuberculosis
Hemolytic anemia	28	1	82	One postoperative death. Four had poor results, all of whom probably had acquired hemolytic anemia
Banti's disease	13	5	19	One died 2 years postoperatively, one died 18 months postoperatively, one still bleeding, one has symptoms of cirrhosis, two lost to follow-up.
Obstruction splenic vein	5	0	50	One has had two or three hemorrhages after operation but none past 3 years
Felty's disease (secondary panhematocytopenia)	5	0	80	One died of sarcoma of thyroid 2 years postoperatively, but relieved of hypersplenism. Arthritis not improved in any
Miscellaneous diseases (cystic Gaucher's disease, atypical aplastic anemia, etc.)	10	1	50	Five had good results but three (with Gaucher's disease, Hodgkin's disease and atypical leukemia) will no doubt die later
Total.	87	7		
Operative mortality rate = 8.0 per cent				

in patients with an advanced stage of the disease. Moreover, in Banti's disease some type of shunt operation (e.g., portacaval) will usually be indicated instead of splenectomy if there has been any bleeding from

esophageal varices. As previously stated, readings on venous pressure should be taken with a manometer in the coronary vein and the portal vein or a major tributary of the superior mesenteric, in order to determine the site of obstruction.

The mortality rate will obviously be less following splenectomy for portal hypertension than after a shunt operation, but it should be remembered that unless the coronary vein empties into the portal, distal to the point of obstruction, hemorrhage from esophageal varices will probably not be relieved by splenectomy; moreover, recurrence of these hemorrhages will usually result in death.

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tution with subsidence of the process and healing, or progression of the disease with massive gangrene and its complications.

CLINICAL OBSERVATIONS

Since clinically it is in the cases with the development of massive gangrene that the greatest morbidity and mortality ensues, excision of the diseased gallbladder or relief of obstruction prior to the development of such an event would logically appear to be the treatment of choice, once this process was initiated. From clinical observations gangrene is stated to develop in from 10 to 20 per cent or higher in cases of acute cholecystitis (see Table 1). Although many observers

TABLE 1
INCIDENCE OF MASSIVE GANGRENE OF GALLBLADDER IN ACUTE CHOLECYSTITIS

Author(s)	Year	Cases	Incidence of Gangrene, per cent
Berk	1940	3506 (collected)	24.6
Fallis and McClure ⁴	1940	320	9.0
Wallace and Allen ¹¹	1941	415	29.4
Glenn and Moore ¹²	1942	350	24.0
Eliason and Stevens ¹³	1944	135	34.0
Lester ¹⁴	1947	109	20.0
Total Average		4835	24.0

have questioned the accuracy of such figures, pointing out that the gross diagnosis by the surgeon usually gives a higher frequency of gangrene than those observations of the pathologist, usually the surgeon is in the most favorable position to note a condition such as focal gangrene which could readily be overlooked by a pathologist receiving a formalin fixed specimen. From our experimental observations it is probable that these figures are too low, for it is now apparent that focal gangrene is common but is easily overlooked except in early phases of the disease, owing to the healing process and progression towards restitution. These small focal areas may be recognized only microscopically and the incidence reported in Table 1 is that of massive gangrene of the gallbladder.

An analysis of cases with respect to the incidence of gangrene at various time intervals from onset of clinical symptoms will correlate experimental and clinical observations as pertaining to the development of gangrene. Unfortunately the recorded data on this point is not as great as would be liked. There are, however, a significant number of observations so that some conclusion may be deduced (see Table 2).

From these clinical observations it is evident that gangrene before

the first forty-eight hours is less frequent than during the ensuing days. In addition, even with gangrene, perforation prior to the fourth day is of unusual occurrence.

As a corollary of these observations, on theoretical grounds, with the presence of devitalized tissue and increasing time intervals the incidence of infection should increase. This has been nicely substantiated by Goldman and his co-workers,² in studies of the bacteriology of acute

TABLE 2

INCIDENCE OF GANGRENE IN ACUTE CHOLECYSTITIS AT INTERVALS FROM ONSET OF SYMPTOMS

Author (s)	Cases	Incidence, per cent					
		48 hrs	48-72 hrs.	72-96 hrs.	4-7 days	8-10 days	710 days
Yetter, W. L. ²¹	121	5.0	13.0	10	—	—	—
Blumberg and Zisserman ²²	82	5.0	10.0	6	13	15	27
McGuigan, W. J. ²³	123	13.6	29.4	5	—	—	—
Wallace and Allen ²⁴	415	In 123 cases of gangrenous cholecystitis, gangrene occurred prior to 4th day in only 10 instances. No perforation noted prior to 4th day, and in only 3 instances did it occur between 4th and 6th day. (64 perforations observed)					
Graham, H. F. ²⁴	198	In the 20 cases with operation before 48 hours, 2 gangrenous gallbladders observed. Ten instances of gangrene were noted in remainder of cases					
Eliason and Stevens ²⁵	135	Average time for perforation of the gallbladder was 6 to 7 days.					
Cowley and Harkins ⁵		Twenty-five cases of perforation of gallbladder studied; in 36 per cent perforation occurred between 1 and 3 days					

cholecystitis Sterile cultures were obtained in 43 per cent of 160 cases. The lowest incidence of positive cultures (35 per cent) was during the first twenty-four hours. The incidence then rose so that, after the third day, the percentage of positive cultures varied from 65 to 80 per cent. After the eleventh day with restitution toward normal, and until the thirty-fifth day, the incidence was only 46 per cent.

From the evidence presented it is apparent both clinically and experimentally that small focal areas of gangrene of the gallbladder in acute calculous cholecystitis are of common occurrence, with their incidence being greatest forty-eight hours after the onset of symptoms.

A RATIONAL APPROACH TO TREATMENT

Immediate Surgery in Early Cases.—With these considerations in mind, a rational approach to the treatment of acute cholecystitis can be made. Ideally, removal of the involved tissues should be performed as soon as possible after initiation of the obstruction. This can be done only if recognition is made of biliary colic as the first manifestation of acute cholecystic obstruction, rather than the passage of a stone with the patient treated thereafter on an emergent basis. At this time the conditions present, i. e., chemically injured or necrotic tissue, are analogous to a contaminated rather than an infected wound. The principles of general surgery permit the excision of such a wound within twenty-four hours of its incurrence and ensuing healing by primary intention. With the employment of the appropriate chemotherapeutic agents this period may be often extended an additional twenty-four hours or more. The organisms encountered are those indigenous to the gastrointestinal tract, viz., nonhemolytic streptococcus, *Bacterium coli* and *Clostridium welchii*,²¹ for which penicillin and streptomycin are of greatest value.

Operation under these circumstances presupposes the previous preparation of the patient for surgery, viz., correction of water, electrolyte and blood imbalance as well as parenteral administration of glucose and amino acids to minimize liver damage. As demonstrated experimentally and clinically, gangrene of the gallbladder is rarely present prior to forty-eight hours after onset of symptoms and the developments prior to that time are pathologically those of acute cholecystitis. With this condition subserosal edema is the most conspicuous feature and cholecystectomy may be actually facilitated by these changes. Excision of the gallbladder is therefore the treatment of choice and should be performed under these circumstances with little hazard to the patient. Because of the nature of the disease process there should be little hesitancy in aspirating the contents of the gallbladder or incising the wall for identification of structures, if such will facilitate removal of the viscus in an otherwise technically difficult case. In some situations, e.g., the general condition of the patient being precarious, cholecystostomy is to be preferred to cholecystectomy. Such a procedure will provide decompression of the obstructed gallbladder and, depending upon the severity of injury already incurred, favor early subsidence of inflammation and healing.

Deferment of Operation in Cases Seen Late.—After the development of large areas of gangrene with or without perforation and superimposed infection, the risk of an operative procedure will outweigh that of conservative treatment. As noted earlier there is a relatively high incidence of gangrene in acute cholecystitis and focal gangrene is probably even more common than is generally realized since many gallbladders that are removed during a quiescent period show, on careful study, areas of the wall including muscularis that have been replaced completely by cicatrix (Figs. 533 and 534). This can be explained only on the basis of

tissue necrosis, with subsequent healing by replacement. In spite of this high incidence of gangrene, there is a relatively low incidence of free perforation into the peritoneal cavity, owing to adherence of neighboring viscera and omentum and immediate walling off of any potential perforation. Attempts to resolve the problem of the advisability of operation under these circumstances on the basis of clinical studies are not entirely successful due to the paucity of reports. The reported operative



Fig. 533.—Gallbladder of a dog two weeks after the production of acute cholecystitis. The muscular layer ends abruptly and has been replaced by cicatrix.

mortality in the presence of gangrene and perforation varies considerably. Eliason and McLaughlin³⁶ collected 348 cases of perforation with an average mortality of 42 per cent; Heuer³⁷ in reviewing 502 cases noted a mortality of 46 per cent; Cowley and Harkins⁵ in observing 433 cases of perforation reported a 20 per cent mortality.

There are an insufficient number of reports to be able to educe or predict accurately the results of conservative treatment in acute cholecystitis. Bachhuber³⁸ followed 895 nonoperative patients admitted with a diagnosis of acute cholecystitis of which fifty-two died, a mortality of 5.8 per cent. Of these deaths only twenty-two were due to gangrene and

perforation bringing the mortality from this complication to 2.45 per cent. It is also his contention that when the overwhelming majority of patients have had one or more previous attacks with spontaneous recovery, the danger of death due to gangrene or perforation in non-surgically treated patients is far less than 1 per cent. Pennoyer²⁹ believes the dangers of surgery in the acute stage are greater in his experience than the natural course of the disease, stating that in almost 90 per cent of cases of acute cholecystitis the manifestations will subside. Thus in observing 241 cases of acute cholecystitis in which subsidence without operation was encouraged, 87 per cent entirely subsided or greatly improved, and 13 per cent did not subside or were getting worse and

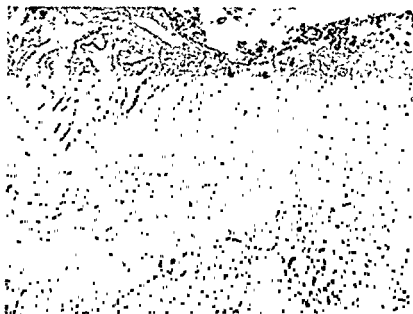


Fig. 534.—Human gallbladder disclosing loss of muscular layer and replacement by cicatrix

operation was carried out in the presence of acute symptoms. Seven deaths resulted in thirty-three patients so treated; the twelve deaths occurred in the entire group treated conservatively. Rupture of the gallbladder with generalized peritonitis was stated to be a rare complication of disease of this viscus. Love⁴⁰ agrees that most cases treated expectantly will subside and in a series of 769 cases of acute cholecystitis so treated, in only nine was intervention necessary. Berk⁴ collected 901 cases of acute cholecystitis (patients observed eighteen hours or less

imen.

obtain

factual information regarding nonoperative mortality of cases of gangrenous cholecystitis complicated by perforation. By inference, however,

from the statistics of Table 1 and the incidence of perforation in acute cholecystitis⁵ with its associated high mortality, if such figures are of prognostic value one would not anticipate conservative treatment to be associated with the low mortality and morbidity observed by Bachhuber, Pennoyer, Love and Berk.

As medicine is practiced now, few cases are seen by the surgeon within the first few days after onset of attack. The problem thereafter is more difficult since clinically it is impossible to predict accurately the conditions present. If such could be ascertained there would be many cases after the first few days in which only the findings of acute cholecystitis would be present. Surgery in these instances would be just as applicable as that during the initial period previously discussed. However, this differentiation cannot readily be made and it is highly probable that, if the condition has existed that long, there will be little more progression, and restitution is more likely to occur without complication. Therefore, on the basis of the above reasoning, deferment of operation with careful observation of the patient is advisable after the initial few days following onset of symptoms. These observations will include temperature, pulse, abdominal tenderness and rigidity, pain, vomiting and the degree of leukocytosis as well as a general evaluation of the patient's condition. Particular significance should be paid to appearance of a mass which indicates extension of disease.⁴¹ Since numerous observers have commented upon their inability to predict the state of the lesion and course of disease^{42, 23, 4, 29, 40, 26} when one or more of these guides indicates progression of the disease with spreading of the process, surgery is indicated. In many instances under these circumstances, drainage of an abscess or cholecystostomy will be all that is warranted. Jaundice may be present and in general the indications for exploration of the common duct are rare at this time. If free bile is obtained at cholecystostomy, the bile passages are decompressed making it safer to remove the stone at a later date. Indeed, the edema about the common duct region is often adequate reason for deferring surgery in many instances. It also must be remembered that it may often take this edema many weeks to subside and, therefore, it is usually technically easier to perform the cholecystectomy at the beginning of the colic or weeks later.

Once a policy of deferment has been carried out, with resultant symptomatic improvement in the patient, there is a distinct tendency toward early intervention. Three to four weeks is probably the minimal length of time for repair and restitution to occur and even at that time in many instances the condition will still be one of "subacute" cholecystitis. Against this postponement of surgery must be weighed the chances of development of an exacerbation of the disease. It may well be that the conditions found at such prolonged intervals after the subsidence of the acute symptoms represent such an asymptomatic exacerbation rather than the slow subsidence of the process. In general, however, deferment of operation for five to six weeks after the subsidence of

symptoms will be rewarded by a technically easier operation with a lesser risk for the patient. One of the reasons for this is that the dissection of the gallbladder, cystic duct, and an accurate anatomical dissection is very difficult. In certain circumstances, it is not unlikely that the operation will be inadequate or that, in an attempt to excise all diseased tissues, there will be resultant injury to contiguous structures and ensuing complications.

SUMMARY

Based on experimental as well as clinical observations, immediate cholecystectomy is advocated in cases of acute calculous cholecystitis when the symptoms appear after onset of symptoms. Thereafter, the tendency of the disease is to extend to the gallbladder, cystic duct, and an accurate anatomical dissection is very difficult. In certain circumstances, it is not unlikely that the operation will be inadequate or that, in an attempt to excise all diseased tissues, there will be resultant injury to contiguous structures and ensuing complications.

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THE REPAIR OF GROIN HERNIAS: PROGRESS IN THE PAST DECADE

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No disease of the human body belonging to the province of the surgeon requires in its treatment a greater combination of accurate anatomical knowledge with surgical skill than Hernia in all its varieties

—Sir Astley Cooper, 1827

The repair of groin hernias represents a practical subject which is essentially surgical in nature, involving many patients. During the past decade, a period beginning with the onset of the war, many advances have been made in the treatment of groin hernias. Unlike developments in certain fields of traumatic surgery, including burns, and even in such conditions as pilonidal sinus, advances in the technic of herniorrhaphy were not directly stimulated by the war; they were for the most part already instituted at the beginning of the war, and were developed only coincidentally with the war. The chief advances in the field involve (1) the general technic of hernial repair (Cooper's ligament method, etc.), and (2) the special use of new suture materials and supportive patches (cotton, stainless steel wire, cutis grafts, whole skin implants, tantalum mesh, etc.). These technics will now be considered, along with changing ideas concerning certain debatable points in the treatment of groin hernias.

During the past decade at least three excellent books on the subject of hernia have appeared. These include Iason's "Hernia" (1941), an encyclopedic text; Watson's "Hernia" (1948), also a complete text with an excellent bibliography; and third, Mair's "The Surgery of Abdominal Hernia" (1948), a smaller book reflecting a more British viewpoint and emphasizing the new method of whole skin implants as supporting patches in hernial repair, a technic introduced by Mair. The account of herniorrhaphy in Maingot's "Abdominal Surgery" is also an excellent one.

ADVANCES IN GENERAL TECHNIC OF HERNIAL REPAIR

Decrease in Popularity of the Bassini Procedure.—This trend has been especially noted in Great Britain since the onset of the past war. Brandon (1945, 1946), Moloney, Gull, and Barclay (1948) and others

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have written disparagingly concerning the method. Brandon worded the title of his 1945 article in a provocative manner: "Inguinal Hernia: The House That Bassini Built." Lunn (1948) succinctly expresses his dissatisfaction with the Bassini operation by stating: "Bassini's operation has no counterpart in nature." Ogilvie (1947) stated: "Bassini's operation spans nothing but makes the weak area still weaker."

Relationship of Inguinal Hernia to Previous Appendectomy.—In a thorough review of the subject, Pitkanen* (1948) studied a large series of appendectomies for the subsequent development of hernia. He concludes as follows.

According to Lehmann the frequency of inguinal herniae is 2.1-2.8 per cent while the frequency of inguinal herniae following operations in my material is 2.4 ± 0.4 per cent, the inguinal herniae in my material might therefore have become manifest also without appendectomy. I cannot therefore state that appendectomy, with all the various factors connected with it, has been a decisive factor in the occurrence of these herniae. If we investigate this question, however, in connection with operations performed at the peritonitis diffusa universalis stage, we shall find that right inguinal herniae occur in 5.9 ± 1.4 per cent of the cases of McBurney's incision and in 5.1 ± 1.3 per cent of the cases of Lennander's incision, which correlation values can also be statistically proved to belong to that class of diagnoses. Therefore, if the peritonitis is far advanced and the incision as well as the period of drainage is long, the operation may be followed by a considerable number of right inguinal herniae in persons who have a congenital predisposition to herniation.

The reasons for the occurrence of inguinal herniae according to literature are when McBurney's incision is employed, injury to the ilioinguinal and the iliohypogastric nerve, and in cases of Lennander's incision, functional disturbances in the abdominal wall. In both these incisions general weakness and injury of the abdominal layers owing to peritonitis are also of importance. Krogius's incision does not seem to influence the manifestation of inguinal herniae.

Thus, if we compare the three appendectomy incisions in question to one another as the causes of right inguinal herniae we shall find, on the basis of my material, that McBurney's incision seems to cause inguinal herniae more frequently than Lennander's and Krogius's incisions.*

Hicks (1941) also stated, "We found that a considerable number of right inguinal hernias followed the McBurney incision for appendicitis. This is, no doubt, due to a blind tearing injury to nerves and muscle when this incision is used." To obviate the difficulty, Hicks has adopted the transverse incision for appendicitis without abscess.

Recurrent Hernia.—The two problems of recurrent hernia are the primary (unsuccessful) operation and the secondary procedure. The rule of Fallis (1941) throws light on this aspect of the subject. The rule is that hernias done in poor clinics recur as indirect ones (because the sac was never ligated properly, if at all), while those done in the better hospitals develop direct recurrences because of the natural tendency of all hernias so to progress. In a good clinic, therefore, emphasis should be

* Pitkanen, A. The Relation of Incisional and Inguinal Herniae as well as of Mechanical Intestinal Disturbances to Previous Operations for Appendicitis with Peritonitis. *Acta Chirurgica Scand* 96: 1-165, 1948.

on doing both primary and secondary operations of a type (e.g. the Lotheissen procedure) which will prevent direct recurrences. Swenson and Harkins (1943) concluded that if the type of repair is proper, nonabsorbable sutures are usually as adequate as fascia in operating on recurrent hernias.

Treatment of Hernia in Infancy and Childhood.—The two problems involved are when and how to operate. Regarding the first of these questions, Larsen (1949) of Vanderbilt University stated: "Hernia in infants and young children should be treated by operation. Operation should not be deferred because of the age of the patient." The other conclusions of Larsen in his excellent summary of the subject deserve consideration. These are:

The truss should not be employed in the treatment of inguinal hernia in infancy and early childhood. The cures are rare, the danger of the hernia is not diminished, the fear of the hernia by the parent and the inefficacy and filth of the truss result in an environment that produces profound emotional disturbances in both the parents and the child.

Compressible hydroceles of the cord or cord and tunica vaginalis are communicating hydroceles and are always infantile hernia.

Noncompressible hydroceles of the cord or cord and tunica vaginalis are noncommunicating hydroceles and in 80 per cent of our cases were accompanied by a definite hernia of the upper portion of the vaginal process.

* * *

It is unnecessary and undesirable to carry out associated Bottle or other operations on the coverings of the scrotal cord and testicle when doing a herniorrhaphy for infantile hernia with or without associated hydrocele

Incarcerated hernia should be operated upon immediately without attempts at reduction.*

With regard to the second question posed above, the type of operation to be used for the repair of hernia in infancy and childhood, there is a definite tendency towards simple herniotomy with sac ligation only, rather than radical herniorrhaphy. The present author agrees with this trend as does Craig (1948) although Larsen (1949) does not, the latter advising a Ferguson type of repair. Sir Lancelot Barrington-Ward (1947) stated in this regard: "Dissection, ligature, and removal of the sac is all that is required. There should be no disturbance of the muscle or fascial arrangements of the inguinal canal."

Treatment of Hernia in the Aged.—The accepted custom in these instances is conservative. It must be remembered, however, that hernias do not grow at a steady rate, but progress in size exponentially and parabolically, particularly in the aged. Because of this, Strenger (1949) recommended operation, concluding:

A series of 82 poor-risk patients have been presented. Sixty-nine per cent had degenerative disease. Fifty-

* Larsen, R. M. Inguinal Hernia in Infancy and Early Childhood Surgery 25: 307-328, 1949.

sistent symptoms from hernia which contributed greatly to their invalidism. Where trusses were worn, they were inadequate. Operation had been deferred for years because of "old age" or a chronic medical condition. In the group of 62 elective cases, one patient died of a cerebral accident and brain tumor 16 days after operation. Of 20 patients subjected to emergency surgery, 8 died. The contrast between the mortality figures in these two groups offers a graphic argument for the elective use of surgery in the treatment of hernia in the aged.*

McVay and Anson (1949) agreed with this opinion, stating: "Advanced age was not regarded as a contraindication to the repair if the patient's general physical condition was good and his symptoms were incapacitating." At least 50 per cent of their patients were over 60 years of age.

The present author tends to agree with them. In the case, the patients themselves prefer the risk of operation to the discomforts of the condition. Since many of the aged are quite thin, the repairs are often quite feasible with local anesthesia.

Treatment of Femoral Hernia with Gangrenous Bowel.—The method of Dennis and Varco (1917) represents a distinct advance in cases where gangrene is present and resection is required. The entire sac and contents are resected intact in order to avoid bacterial contamination of tissues to be used for repair. This is accomplished by freeing the sac and contents above without releasing the neck. The peritoneum is opened parallel with the oblique skin incision, involved omentum is cut and ligated close to the neck and the mesentery of the small intestine entering the sac divided from the proximal to the distal side of the incarcerated intestinal loop. Each limb of bowel is clamped by two Ochsner clamps and the intestine divided between them with the cautery. The inguinal ligament is then divided near its attachment to the pubis and split laterally, enough of the heavy aponeurotic tissue being left in front of the neck of the sac to prevent it from relaxing and releasing the contaminated contents. The entire sac is then freed by dissection down to the remains of the ring which is cut under direct vision and the complete contaminated mass removed without soiling the field. The internal oblique and transverse abdominal muscles are sutured to Cooper's ligament as far as the femoral vein and to the inguinal ligament lateral to this.

The importance of the nature of the contents of the sac in strangulated femoral hernia has been shown by Jarboe and Pratt (1919).

Size of the Subcutaneous Inguinal Ring.—In physical examinations much is made of the size of the subcutaneous or external inguinal ring as an indication of both potential and actual inguinal hernia. In an excellent review, Chassin (1917) found less correlation than would be expected between these factors. A study of 3199 soldiers between 18 and 36 years old was made to determine the range of sizes of subcutaneous or external inguinal rings in large numbers of healthy young men. It was

* Strenger, George: The Surgical Treatment of Hernia in the Aged. A Study of Eighty-two Consecutive Patients over Sixty Years of Age. *Ann Surg* 129: 238-243, 1949.

found that 78.1 per cent of these men had external rings sufficiently large to admit the index finger, almost half being 1.4 to 1.9 cm. This does not agree with the previous statements of many authorities and indicates that normal external rings vary widely in size and the average is appreciably larger than formerly believed. In 724 men with asymmetric rings, the larger occurred on the left side in 57.5 per cent, but 58.3 per cent of inguinal hernias discovered during this study occurred on the right side. There was no convincing evidence to indicate that a large subcutaneous ring is abnormal or that it predisposes to future herniation. No correlation could be demonstrated between the size of the subcutaneous ring and the weight or height of the subject.

Femoral versus Inguinal Approach for Femoral Hernia Repair.—There has been a definite trend towards a wider adoption of the inguinal approach. On the other hand, Waugh and Hausfeld (1942) reported on the use of a femoral approach with sac removal without attempting to close the femoral canal (Socin-A. J. Ochsner technic). Waugh and Hausfeld used the method in twelve cases of simple femoral hernia with good results. They did not advise the technic in complicated or strangulated cases. Birt (1947) advised the femoral route for nonstrangulated hernias, and the inguinal route for strangulated femoral hernias.

Injection Treatment.—The injection treatment of hernia has suffered a progressive decline in the ten year period ending with the present report. This was influenced by several factors: (1) The method had never really gained a foothold in the larger surgical centers; (2) improvements in the results of the operation made a substitute procedure less necessary; (3) the unsurgical nature of the method combined with the difficulties produced by varying positions of the sac made it have little appeal to experienced surgeons; and particularly, (4) the unfavorable report of the Council on Chemistry and Pharmacy of the American Medical Association on August 17, 1940. Recently Lawrence (1948) has published a case report concerning fatal intestinal obstruction following injection treatment of hernia. This author believed the method to be unreliable and hazardous. With this opinion, the present author is in accord.

Disposal of Distal Portion of the Indirect Sac.—In many clinics great care is taken, after dividing a long indirect sac, not only to close the proximal end but also to excise the remaining distal segment because of fear of developing a hydrocele. We believe that while high ligation of the proximal stump of the sac is the most important step in the repair of hernia, in most instances it is preferable to leave the distal portion of the sac in place. In cases of congenital hernia we do not generally even do a Bottle type of operation in the absence of a pre-existing hydrocele. The rationale behind this mode of treatment is that an almost certain danger of hematoma (from sac excision) is more to be feared than the more remote possibility of hydrocele. (1949) speaking of hernias in infants that the distal portion of the sac is

Simple Herniotomy.—There is more and more universal agreement

that certain hernias (congenital indirect sacs in infants, children or young adults) are best treated by simple herniotomy while others (indirect inguinal hernias in older persons with weak tissues, direct and femoral hernias) are preferably managed by a type of radical repair whether that be the herniorrhaphy of Halsted (original), Bassini, Ferguson or Lotheissen. Mair (1948) discussed the use of herniorrhaphy and herniotomy as follows:

The indications for simple herniotomy are absolute. They are: (1) All infants (2) All children (3) All small indirect inguinal herniae in adults where the muscle and sphincteric tone of the canal is good (4) Moderate-sized indirect herniae of adults where the muscles and sphincters are in a state of temporary weakness, as, for example, after illness associated with onset of a hernia, but where recovery will be associated with local and general increase in muscle tone.

The contra-indications to simple herniotomy are: (1) All direct and recurrent inguinal herniae. (2) All large and chronic herniae where muscle and sphincteric tone in the canal has been lost (3) Where there is an associated factor predisposing to recurrence, such as chronic bronchitis, bronchiectasis, or the need to continue in an occupation causing severe physical strain when the patient is elderly and the hernia large (4) Obesity accompanied by muscle flabbiness and excess of extra-peritoneal fat (5) All traumatic herniae (6) All sliding herniae

The results of simple herniotomy are excellent in the correct case *

Cooper's Ligament (Lotheissen, McVay) Technic.—The present author believes that the current interest in this method occurring in this decade starting in 1939 is the most important trend in the treatment of groin hernia since the new developments beginning in 1889 with the work of Bassini and Halsted.

Following Narath's use of the Cooper's ligament technic as cited in Lotheissen's classical article on the subject (1898), the method has been used by the following authors: Fischer (1919), Groves (1923), Stetten (1923), Andrews (1921), Keynes (1927), Dickson (1936), Gomard (1939), McClure and Fallis (1939), Heritage (1940), McVay (1941), Amendola (1941), Neuhoof (1942), McVay and Anson (1942), Harkins, Szilagyi, Brush, and Williams (1942), Anderson (1943), Harkins and Swenson (1943), Swenson and Harkins (1943), Brunkow (1943), Hyde (1945), Sauer (1945), Lick and Sampson (1945), Parsonnet (1945), Ross (1945), Clark and Hashimoto (1946), McLaughlin and Brown (1946), Mattson (1946), Blodgett (1947), Burton (1947), Dennis and Varco (1947), Collier (1947), Garner (1947), Harkins and Schug (1947), Farris (1948), Donald (1948), Holloway and Johnson (1948), Watson (1948), Lunn (1948), Rice and Strickler (1948), and McVay and Anson (1949). The method was cited in a Query and Minor Note (J.A.M.A. 1945) and is listed in Watson's "Hernia" (Third Edition, 1948) as a method of choice in the treatment of both inguinal and femoral hernia.

The suture of the transversalis fascia or of the "conjoined tendon" to Cooper's ligament is, according to Brunkow (1943), "likened to pulling the curtain clear to the base of the window instead of only halfway for an

*Mair, G. B.: The Surgery of Abdominal Hernia. Baltimore, Williams & Wilkins Co., 1948.

effective blackout." The same procedure can also be compared with tucking the sheets in at the foot of the bed so that the toes of a tall person will not protrude.

Anderson (1943), in discussing the causes of failure in repair of inguinal hernia, stated:

It is obvious that when the transversalis fascia is attached to Poupart's instead of Cooper's ligament an undesirable pocket is left. That is, the normal insertion

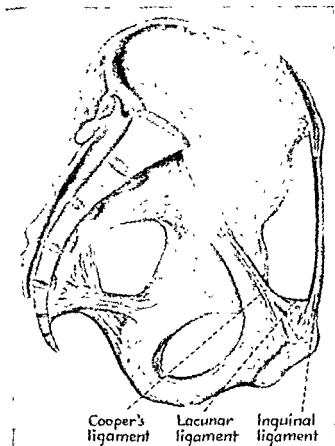


Fig 535.—Cooper's ligament. View of the left half of the pelvis with attached ligaments. The relationships between the firmly anchored Cooper's ligament and the loose inguinal ligament are clearly shown.

and attachment of the transversus aponeurosis and transversalis fascia in this region is into the rectus sheath medially, then into the pubic bone and outward

from the rectus sheath, the potential beginning of a recurrent hernia. . . In the case of hernia and then the

Insertion and insertion—Cooper's ligament *

* Anderson, R.: Failures in Inguinal Hernia. *Canad. M. A. J.* 49:392, 1943.

Lunn (1918) spoke of the use of Cooper's ligament as follows: "The conjoined tendon is attached in nature to the pectineal surface of the pubis and requires reattachment in many cases of hernia. Reconstructive operations for a failed inguinal sphincter are better assured of a firm foundation if they are based on Astley Cooper's rather than on Poupart's ligament."

In their recent excellent review of the subject of anatomic hernial repair, McVay and Anson (1949) stated: "Since there is no anatomic defect in the inguinofemoral region in the uncomplicated small indirect inguinal hernia other than the presence of a congenital hernial sac and a slight dilatation of the abdominal inguinal ring, it is recommended that this type of hernia be repaired by removal of the sac by accepted methods and by subsequent tightening of the abdominal inguinal ring." It is also our opinion that when one speaks of a small indirect inguinal hernia the diminutive should refer to the diameter of the neck of the sac rather than its length.

One of the few recent criticisms of the Cooper's ligament technic is that of Zimmerman (1948) in an editorial in *Surgery, Gynecology, and Obstetrics*. This author made the following comments concerning the theoretical advantages of the method:

1. He stated that the objection to the use of Poupart's ligament that it fails "because of lack of fixity of the structure to which the abdominal strata are sutured" is invalid because if this were so recurrences would occur below Poupart's ligament in the femoral region. It would seem to the present author that not only the lack of fixity but also the relatively superficial position of Poupart's ligament is a deterring factor. Orthopedists who do tendon transplants know that the angle of pull of muscles is important. If the transversalis fascia normally inserts into Cooper's ligament, this situation should be restored.

2. Zimmerman also pointed out that the Cooper's ligament technic is more difficult technically. Granting that this is so, although the increased technical difficulty is, in the present author's opinion slight, added technical difficulty is not in itself an argument against an otherwise superior operation. It is well known that the recurrence rate of the Poupart's ligament technic in most operator's hands is high (and particularly so in the hands of those to whom the increased difficulty of the Cooper's ligament technic might be a deterring factor). A somewhat similar situation exists in the field of surgery for peptic ulcer where admittedly gastroenterostomy is simpler technically than gastric resection, yet most clinics advise gastric resection in the majority of surgical cases.

3. Zimmerman stated that the lateral portion of the inguinal canal cannot be closed in the Cooper's ligament technic "because of the presence of femoral vessels crossing the superior pubic ramus." This is certainly true if the repair is looked at from a purely nonfunctional and anatomic basis. However, with the transversalis fascia (and conjoined tendon) sutured deeply, contraction of the muscles closes the opening. This muscular closure is prevented when the aponeurotic structures are

sutured superficially to Poupart's ligament. Incidentally, Zimmerman goes on to state: "In order to close this [the lateral] portion of the canal, Harkins [Harkins and Schug, Arch. Surg. 1917, loc. cit.] who has enthusiastically endorsed the McVay method, sutures the lateral portion of his fascias to the inguinal ligament." Not only does the present author not do this, stating to students that it defeats the functional purpose of the operation, but re-examination of the paper referred to (Harkins and Schug), reveals no place where this is advised in either text or illustrations. *In all fairness it should be said, however, that Zimmerman's words of caution are appropriate and only time will give a definitive answer as to the ultimate superiority of Cooper's or Poupart's ligaments as the lower anchor of the repair of an inguinal hernia.*

Burton (1948) gave the following criteria for the use of the Cooper's ligament mode of repair:

- | | |
|---|-------------------------|
| (a) All femoral loculations of the sac | } absolute indications |
| (b) Inadequacy of the inguinal ligament | |
| (c) Arborization of the sac | } equivocal indications |
| (d) Generalized laxity of the inguinal wall | |
| (e) Widening interligamentous space | |
| (f) Refractory hernias | |

The present author would list the indications for the method as follows:

Indications:

- (a) Femoral sacs
- (b) Direct sacs
- (c) Recurrent groin hernias of any type
- (d) Indirect hernias in older persons or in those with weak structures

Contraindications:

- (a) Indirect hernias in infants, children, or in healthy adults with strong structures

Generally speaking we do either a Cooper's ligament herniorrhaphy or a simple herniotomy with high sac ligation. There seems to be little indication for halfway measures such as the Bassini type of repair which we feel to be unnecessary in congenital indirect hernias in children and inadequate in direct hernias.

McVay and Anson (1949) agreed that the three groin hernias present similar problems (except the small indirect inguinal hernia). These authors stated: "A single operative procedure is presented for the repair of large indirect inguinal, direct inguinal and femoral hernias. This operation consists essentially of restoring inguinofemoral anatomy to normal status. Repair is similar because the three types of hernias represent defects in the same layer at different points."

TECHNIC: COOPER'S LIGAMENT METHOD

General Principles. 1. Silk sutures were used in all cases except in a few where cotton or fascia was utilized (the latter in conjunction with silk).

2 The patients are at present allowed to get out of bed the evening of the day of operation.

3 Except when the hernias are large or the patients in poor condition, we will repair both sides of a bilateral hernia at one operation.

Step-by-Step Procedure. The operation can be divided into ten steps as follows:

Step 1 Exposure of the Cord and Opening of the Indirect Sac.—The incision in the skin is made from 1 cm. medial to the anterosuperior

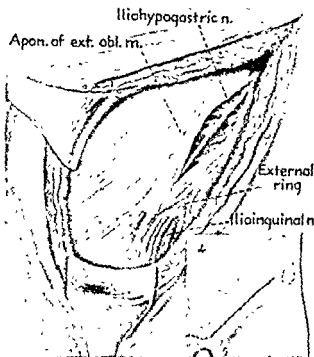


Fig. 536 —Cooper's ligament herniorrhaphy. Incision of the skin and beginning of incision of the external oblique aponeurosis. The external oblique aponeurosis is usually opened in the direction of its fibers so that the opening will be even with the upper border of the external ring. The underlying iliohypogastric nerve is carefully avoided.

iliac spine to over the pubic spine, which exposes the external oblique aponeurosis. The external ring is exposed and the external oblique aponeurosis split in the direction of its fibers even with the upper border of the ring to allow for an adequate lower flap. This splitting with the scalpel is best begun 3 cm. from the ring, as shown in Figure 536, to avoid the nerves where they are adherent to the ring. The split is then extended laterally and upward with scissors and then downward in the direction of the external ring after the iliohypogastric nerve, which is often adherent to the under surface of the external oblique aponeurosis at this level, has been carefully peeled away. When cutting occurs accidentally, it is usually near the external ring, and it may be prevented by approach-

ing the latter from the lateral side. The cord and the surrounding structures are then separated from the lower leaf of the external oblique aponeurosis and Poupart's ligament and then from the region of the pubic spine and conjoint tendon so that finally the cord is freed entirely except at both ends. The indirect sac, which is always present even in normal persons, is located upward and medially from the internal ring.

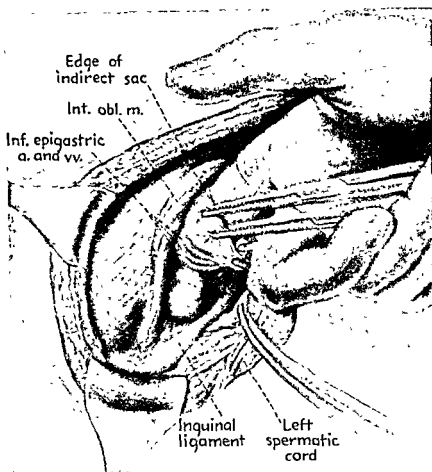


Fig 537—Cooper's ligament herniorrhaphy. Exploration through the opened indirect sac. The latter is always opened and any femoral or direct sac is transposed by the method of Hogue to become part of the indirect sac.

The indirect sac is opened in all cases, whether the hernia is indirect inguinal or femoral. In many instances of direct inguinal hernia or femoral hernia the indirect sac will be normal in size, but it can always be found above and medial to the cord. In cases of complete indirect inguinal hernia of the congenital type or in patients in whom the hernial sac is long the latter is cut across near the internal ring and separated from the cord. The proximal end is closed by an internal purse string suture, as outlined later, while the distal end is left in place. Many surgeons are of the belief that to leave the distal sac in place will cause hydrocele. This has not been our experience, and we believe that the

hematomas that result from the removal of the distal sac are far more disastrous than any theoretic occurrence of hydrocele.

Step 2. Exploration of Hesselbach's Triangle and of the Femoral Ring.—Once the indirect sac is opened, it is a simple matter to insert the gloved finger and feel Hesselbach's triangle for a direct weakness or obvious direct hernia and to feel the femoral ring. It is indeed surprising how few surgeons will take the extra thirty seconds needed to perform this exploration, and many femoral and direct hernias that "recur" are overlooked because this maneuver was not performed. Exploration of the

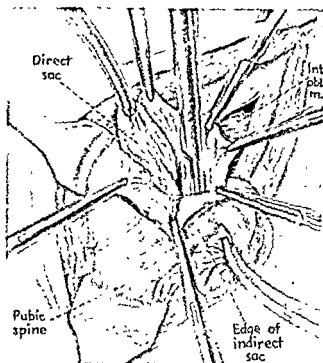


Fig. 535.—Cooper's ligament herniorrhaphy. Hoguet's maneuver. The direct sac has now been transposed and the gauze-tipped Kuttner dissector is holding back the intestines.

femoral ring and Hesselbach's triangle with the finger tip as shown in Figure 537 should be an essential feature of the repair of all hernias.

Step 3. Hoguet's Maneuver—Transposition of Direct or Femoral Sacs into the Indirect Sac.—If a direct sac is present as shown in Figure 538, it should be transposed laterally to the inferior epigastric vessels by the technic of Hoguet (1920), which has since been popularized by Fallis (1938). Thus, the direct and indirect sacs are converted into one. This step may be described in Hoguet's own words as follows: "By traction outward on the indirect sac, all of the peritoneum of the direct sac may be pulled external to the vessels and the two sacs converted into one. An indirect sac can always be found in these cases, although it may be

very small." The same procedure can be used to convert a femoral sac into an indirect sac, as practiced by McClure and Fallis (1939). This maneuver is extremely useful. In general, no matter how large a direct sac is, it is not opened but is merely transposed. In the case of large direct sacs the transversalis fascia can be infolded with numerous interrupted silk sutures. One advantage of not opening a direct sac is the fact that the danger of opening the bladder is largely obviated. In some instances

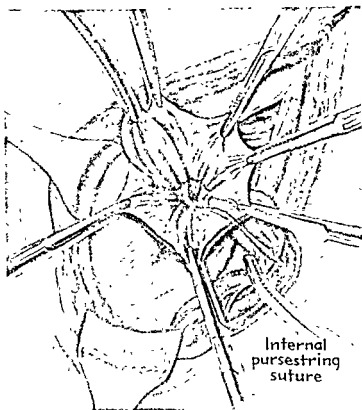


Fig. 539 —Cooper's ligament herniorrhaphy. Internal purse string suture. This suture completely closes the sac and by small bites obliterates all its folds. The redundant sac (proximal to its division and distal to the purse string suture) is usually placed inside the internal ring but, if large, may be excised.

all three sacs can be converted into a single indirect sac, which in turn can always be dealt with as described in Step 4.

Step 4. Internal Purse String Closure of Indirect Sac.—The indirect sac, whether it is simple or enlarged by the added conversion of direct and femoral sacs, is then closed with an internal purse string suture of medium or heavy silk, as shown in Figure 539. Many stitches are taken with a round noncutting needle so as to include all crevices. Such a closure is done as high as possible to prevent indirect recurrences, although the sac is not attached beneath the abdominal wall as is done by Collins (1942).

Step 5. Plastic on the Internal Ring—MacGregor's Maneuver.—When the free ends of the purse string are cut and the peritoneum snaps back,

the defect in the transversalis fascia at the internal ring is seen to be large and in many instances will admit even three or four fingers. The fascia is grasped with Allis clamps at numerous points around the internal ring above and medially as far as the inferior epigastric vessels—but not entirely around the circumference inferior to the cord—and a second partial or semilunar purse string suture of medium or heavy silk is made in the transversalis fascia. This ensures a snug fit around the cord, but the purse string itself does not surround the cord. Essentially this step involves the suturing of the transversalis fascia, Henle's ligament and cremaster muscles together. Occasionally the conjoined tendon may be included in the sutures, but the shelving edge of Poupart's ligament should not be included since the normal and desirable retractile sphincter-like action of the internal ring demonstrated by MacGregor (1929, 1930, 1945) would be interfered with. The use of Henle's ligament has been especially described by Clark and Hashimoto (1946).

Step 6. Relaxation of the Internal Oblique Muscle.—The inner layer of the anterior rectus fascia is usually split for a distance of about 3 inches (7.6 cm.) from a point 2 cm. above the pubic spine upward and laterally. This is done almost exactly as described by Rienhoff (1940) and as shown in Figure 540. The external oblique aponeurosis is lifted up by the assistant and the internal oblique aponeurosis cut just lateral to the junction of the two to where they form the linea alba. The rectus and pyramidalis muscles are exposed. The iliohypogastric nerve and the adjoining nerves and vessels which enter the rectus muscle through the internal oblique aponeurosis at this point can be avoided easily. This relaxation allows the internal oblique and the attached transversalis fascia to be pulled down for the subsequent repair without tension.

Step 7. Sutures into Cooper's Ligament.—The "red" muscle of the internal oblique is entirely disregarded and even may be excised for convenience where it overlies the conjoined tendon. Usually it is elevated with a small retractor and the conjoined tendon located with a gauze (Kuttner) dissector. If the transversalis fascia appears strong enough, it alone is used for the upper leaf of the repair. If it is not adequate, one must go higher and include the internal oblique aponeurosis. In no instance should "red" muscle be used. The transversalis fascia, and often the conjoined tendon, therefore, forms the upper leaf of the repair, while Cooper's ligament is the lower leaf. As stated previously, Cooper's ligament is an extremely tough thickening of the periosteal structures on the anterosuperior surface of the anterior ramus of the pubis.

During the first year or so that this repair was used, Cooper's ligament was visualized by breaking down Hesselbach's triangle. Then for a year or so the sutures were applied blindly, Hesselbach's triangle being left intact. Recently, however, there has been a return to the principle of direct visualization of Cooper's ligament, it being decided that it is easier and safer to apply the sutures when there is direct vision, and during the past four years we have routinely visualized Cooper's ligament. McVay (1947) used the method of direct visualization. After

separation of the fascia over the anterior ramus, Cooper's ligament is exposed. The left index finger is placed on the anterior ramus of the pubis near the spine and moved laterally along the crest until the femoral vessels are reached. This is usually about 4 cm. lateral to the spine of the pubis. Since the finger is held in close contact with the bone, the vessels being kept lateral, and the first stitch is placed medial to the finger, there is little danger of damaging the vessels. The first stitch is thus

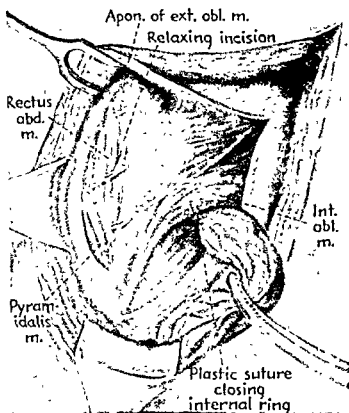
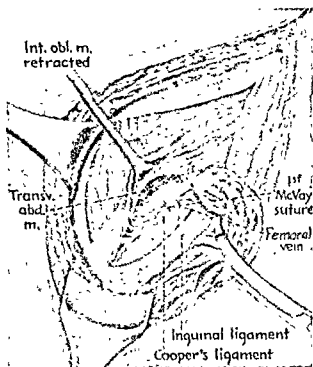


Fig. 540—Cooper's ligament herniorrhaphy. Plastic closure of internal ring and relaxation of internal oblique muscle.

An attempt is made to spare the nerves and accompanying blood vessels.

usually 3 to 5 cm. lateral to the pubic spine. Therefore, since the upper leaf is to be grabbed with the suture first, the needle goes through the transversalis fascia a corresponding distance of 3 to 5 cm. from the pubic spine and then through the thick Cooper's ligament on the upper border of the pubic ramus. The stitch is then tied as shown in Figure 541 and the intervening gap between this point and the pubic spine is closed with three or four similar sutures, as shown in Figure 542. The most medial sutures usually go through Gimbernat's (lacunar) ligament as well as Cooper's. It is important that the most lateral suture be placed first, as otherwise it is more difficult to protect the vein. The sutures into Cooper's ligament are of double heavy 0 to 00 silk and are applied with a

small (No. 7) round curved Mayo needle, which is best held with a Bland or a Jones needle holder. The double strands are made into a double (or triple) knot, and then the individual strands are separated and tied in pairs (this is called "braiding") We have found the braiding technique to be useful in other operations where we are especially anxious that a double suture not become untied and yet the making of the knot is difficult because of the depth of the wound. The relatively large amount



of silk used has seldom caused trouble. In certain cases, because of the prominence of Rosenmüller's gland (a lymph gland lying over Cooper's

suture on the internal ring often seems to be a possible

those doing the operations for the first time. Actually this is not so, because the arched internal oblique muscle will tend to close this defect on contraction. Any attempt to tighten it by suturing the internal oblique or conjoined tendon to Poupart's ligament as is done by Baritell (1944) and others defeats the purpose of the operation in my opinion. Such a suture interferes with the spincter-like action of the internal ring and tends to pull the transversalis fascia away from the Cooper's ligament.

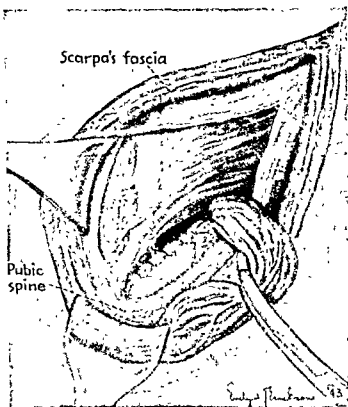


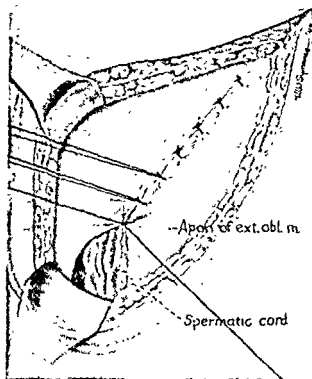
Fig 542.—Cooper's ligament herniorrhaphy. Completion of Cooper's ligament sutures. Usually four or five such sutures are introduced, the most medial of which also pass through the lacunar (Gimbernat's) ligament (Modified by H. W. Symmes; original drawing by Evelyn Erickson. (Author's article in Arch. Surg., December, 1947.)

If such a suture were done it would mean that after carefully fastening down the conjoined tendon we would try to pull it superficially again.

Step 8. Closure of the External Oblique Aponeurosis.—In the first third of this series of cases the external oblique aponeurosis was closed beneath the cord after the manner of the original Halsted-I procedure in the majority (61 per cent). In the more recent two thirds of the series, however, it has most often been closed over the cord (Fig. 543), the latter being dropped into the dead space left by the closure. Thus more recently the usual closure of the external oblique has been done in a typical Bassini manner (97 per cent). We call these two variations of the procedure the Halsted-I-Lotheissen and the Bassini-Lotheissen or Cooper's

ligament repair with and without, respectively, subcutaneous transplantation of the cord.* There has been one recurrence when the former method was used and two when the latter was used. In both procedures the external oblique is closed with interrupted line or medium silk sutures, little if any imbrication being used.

Step 9 Closure of Scarpa's Fascia—Closure of Scarpa's fascia with small bites of the suture seems more sound anatomically and leaves less



The cord is
ire),
over

silk than does suture of the fat with large bites taken at random. This closure is especially important with a Halsted-I type of repair as it gives the already superficial cord additional protection. The sutures are preferably placed so that the knot will be down.

Step 10. Closure of the Skin.—Interrupted sutures of silk are advisable for this step. The proper closure of the lower third of the wound inside the hair line is of especial importance.

Additional Features in Technic. Ross (1945) described a special needle

* For a clarification of the terminology of eponyms in connection with some of the operations for groin hernias, particularly by Dr. Halsted, see Koontz, 1949.

for suturing Cooper's ligament in performing a Lotheissen procedure. The present author has used the Jones needle holder and prefers a No. 7 Mayo needle either with the Jones or an ordinary needle holder. Rothchild (1947) sutured Cooper's and Poupart's ligaments and the conjoined tendon all together (i.e. a combined Lotheissen and Moschcowitz procedure).

Use of Wire Sutures Through the Pubic Bone.—In three recent cases (the patients were males aged 59, 82, and 57) Cooper's ligament was found to be partially or almost completely deficient. In these instances drill holes were made through the anterior ramus of the pubic bone adjacent to the sites where the ligament would have been sutured. Stainless steel wire sutures were then passed through the drill holes and sutured to the conjoined tendon in the usual manner. These three patients had a repair of a recurrent right indirect inguinal, a right direct inguinal, and a recurrent right indirect inguinal and femoral hernia respectively. In all three instances the immediate result was good.

TABLE 1
SEX OF PATIENTS

	Num- ber of Pa- tients	Per- cent- age
Male	311	97
Female	9	3
Total	320	100

MATERIAL: COOPER'S LIGAMENT METHOD

Using the method as described in the ten steps above, 398 hernias have been repaired during the past nine years. The operations were done by the author (232 hernias) and by sixteen members of the resident staff under his direction (166 hernias). During the past two years no cases by residents were included (except two which were contralateral repairs where both sides were done at the same operation and one side was done by the author). This recent exclusion is to avoid inclusion of cases done with too many minor variations.

Sex.—The predominance of males in this series (97 per cent, as shown in Table 1) reflects the usual sex difference, which is much exaggerated by the industrial occupations of the clientele.

Side.—The right side was operated on most often, as shown in Table 2, while in seventy-nine instances a bilateral repair was performed. The table refers to this type of operation only; in several instances, especially early in the series, procedures were done on the other side which are not listed. In every such instance the operation through Cooper's ligament was performed on the side with the largest hernia. For technical reasons a Lotheissen operation on the left side is more difficult for a right-handed surgeon than a similar operation on the right side.

careful animal experiments. In two cases where the skin implant was examined later in human subjects, it was found to be converted into stout fibrous tissue Mair stated:

In my own practice I have repaired 140 indirect inguinal herniae with the whole skin graft technique and with a recurrence rate of 0.71 per cent after a follow-up of 1 year. I have also repaired 40 direct inguinal herniae by the same technique without a recurrence at the end of 3 years. This is associated with a morbidity rate, both immediate and remote, which compares well with figures from both my own practice and results from other clinics for other methods. These figures embrace those repairs performed with skin only over a short period.

So far I have found no contra-indication to the routine use of the operation where sound repair is indicated, but insist on an adequate pre-operative skin preparation as being essential to elimination of sepsis as a complication.*

West and Hicks (1918) have also reported favorably on the use of whole skin grafts in the repair of inguinal hernia, particularly recurrent cases, and femoral hernia. The method has also been used successfully at the University of Tennessee (Wilson, 1918).

Darning and Filigree Technics.—These are especially popular in Great Britain where faith in the classical Bassini operation is beginning to falter, and reliance has not yet been widely placed in the Cooper's ligament technic. Maloney, Gill, and Barclay (1918) advocated a technic using nylon darn. While the incidence of infected sutures reported was small, this method of using a continuous buried nonabsorbable suture seems inadvisable to the present author for routine work.

Vitallium Plate.—The use of such a buried support was advised by McNealy and Glassman (1916).

Tantalum Mesh.—The use of tantalum mesh as a reinforcing patch in hernial repair has been advocated by several authors including Koontz (1919), Jefferson and Daily (1918), Lam, Szilagyi and Puppen-dahl (1948) and Throckmorton (1948). The present author has used tantalum mesh for two incisional hernias, but not for a groin hernia as yet.

CONCLUSIONS

The surgical treatment of groin hernias has advanced considerably during the decade just ended. The chief developments in the field include:

1. *Improvements in general technic and operative indications:*
 - (a) Use of an earlier but more conservative type of operation for hernia in childhood.
 - (b) A more radical approach to the subject of hernia in the aged.
 - (c) Introduction of the Dennis and Varco method of dealing with femoral hernia containing gangrenous bowel.
 - (d) An increased use of the inguinal approach in dealing with all types of femoral hernia.
 - (e) A decreased use of the injection treatment.

* Mair, G. B.: The Use of Whole Skin Grafts as a Substitute for Fascial Sutures in the Treatment of Hernias. Preliminary Report. *Am. J. Surg.* 69:352, 1945.

2. Wider use of the Cooper's ligament technic for direct, femoral, and large indirect hernias as a means of restoration of the normal anatomic continuity of the involved structures.

3. Advances in the special use of new suture materials and supportive patches.

(a) Nonabsorbable sutures or patches (exogenous): silk, cotton, stainless steel wire, vitallium plate, and tantalum mesh.

(b) Endogenous sutures or patches: fascia, cutis and whole skin.

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EARLY DIAGNOSIS OF CANCER OF THE KIDNEY

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There is but one cure for cancer of the kidney: the surgical removal of all malignant tissue. Every advance to this end must be directed toward early recognition of the disease, as the early days of the localized malignant change offer the only opportunity for favorable surgical intervention.

SYMPTOMS

The principal symptoms of renal tumor, as frequently considered, are associated all too often with a large cancer that is either inoperable or offers an unfavorable prognosis with surgical removal. These symptoms are hematuria, mass in the kidney region, possibly some discomfort or pain associated with the mass, or urinary infection. Any of these symptoms, singly or in association, may or may not be a warning of cancer of the kidney. In any case, there is but one safe diagnostic policy: to locate the etiologic factor which started the symptom or chain of symptoms. Pain or hematuria may first be caused by a tumor, and infection of the urine may be secondary; or this relationship can occur in the reverse order.

Urinary Infection.—Infection of the urine is invited whenever the highly specialized epithelial lining of the urinary tract can be invaded. Organisms normally are excreted daily in the urine. When, in their passage through the urinary tract, they meet with traumatized, ulcerated or roughened epithelium, or when the urinary flow is slowed down (stasis or relative stasis) in its passage, either within a blocked calyx, pelvis, ureter or bladder, or when the excreted bacteria meet with an unusually favorable growth medium, such as blood or sugar in the urine, they have an opportunity to multiply more rapidly. With their abnormally increased numbers, they now invite a clinical infection.

Cancer in its development may invite infection early or late; this depends upon whether it ulcerates or sufficiently blocks the urinary flow. Obviously, therefore, a malignant growth starting near the pelvis may invite our attention earlier in its development than one situated deeply within the renal cortex.

Hemorrhage.—Hemorrhage certainly is the cardinal warning sign, and every effort should be made to locate the source of the blood when

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noted for the first time in the urine. When possible the patient should be cystoscoped while bleeding. Blood may be seen spurting from a ureteral orifice. When an acute cystitis is associated, cystoscopic examination may be delayed for only a few days.

All too often we are given the history—"I passed blood six months ago but I got well", which always means, in dealing with cancer, that it has gained an advantage. Possibly the patient has been given urinary antiseptics, and the drugs erroneously are credited with stopping the bleeding. And, of course, we well know that gross bleeding is often periodical, although in the "clear urine" periods occult blood can always be found microscopically in the centrifuged specimen of urine.

Masses.—Tumors of the kidney should be diagnosed before a mass is palpable, but unfortunately this is not always possible. This must become increasingly possible if we are to effect a higher percentage of cures. It is a distinct challenge to every physician, that he use all of our implements of diagnosis at the first symptom; and to the laity that they report to the physician with the first symptom.

Pain.—Malignant tissue is not innervated, therefore sensation is transmitted by it to outside nerve terminals. Pain may occur during the first days of infection, and also with ureteral passage of blood clots. Obviously, when due to growth of a tumor, pain is a late symptom, and is a dangerous one to wait for.

STEP-BY-STEP INVESTIGATION

Probably the greatest advance toward the early diagnosis of any urinary tract disease, including *early* cancer of the kidney, would be the acceptance by physicians of one diagnostic plan—an orderly procedure coordinating all of our new and old information, diagnostic procedures and types of examination. This would insure a step-by-step investigation in all cases, until the urinary disease is diagnosed. Such a method would include the following steps, in the order given:

1. HISTORY

The history should be taken by the physician, who visualizes the entire urinary tract and searches this tract in his mind for the origin of the infection and the process involved. The attention should be directed to the first symptom involved.

Pain originating in either lobe must be investigated by x-ray, while dysuria should invite our immediate attention as to why either the bladder or the urethra first became involved.

2. PHYSICAL EXAMINATION

Bimanual palpation of each kidney region and palpation and percussion of the abdomen, ureter and bladder region are indicated. Rectal

examination is made to determine the tone of the anal sphincter and the size, shape and consistency of the prostate. The anal tone provides a clue as to whether dysfunction of the bladder, with infection and/or hematuria, could be of neurogenic origin,¹ and physical changes in the prostate could invite infection or hematuria.

3. EXAMINATION OF THE URINE

In the male a two-glass test should always be made in either infection or hematuria. When glass 1 shows more infection or blood than glass 2, we can consider that the source of bleeding or the principal infection is located between the meatus and the internal bladder orifice. When, however, glass 1 and glass 2 show an even admixture of infection or blood (and by infection I refer to pus cells and bacteria noted by methylene blue stain), then the abnormal urine definitely comes from the bladder. This is the only place an even admixture could occur, whether the actual source be bladder, posterior urethra or kidney.

Terminal hematuria suggests that the increased amount of blood seen in glass 2 originates from the posterior urethra or from the bladder mucosa, when their opposing surfaces meet at the completion of urination.

Hemospermia, bloody ejaculate, is usually associated with urethral prostatic lobes, from which, with contraction of ejaculation, blood is literally rubbed from the opposing mucosal surfaces.

Hematuria is frequently associated with primary kidney or bladder infection, and even more frequently with cysto-urethroceles with a residual urine. Glomerular nephritis must be kept in mind; with it, however, we do not expect clotting or gross bleeding. In our analytical diagnosis of cancer of the kidney microscopic examination of the urine is of the greatest importance. Low power examination of a drop of centrifuged urine, properly lighted, points out blood, motile bacilli, and casts. Frequently a subsequent methylene blue stain of a centrifuged specimen of urine is necessary to determine the presence of organisms. Culture is used to identify the organism. Pus in both glass 1 and 2, without organisms, is suggestive of tuberculosis. Its diagnosis requires stain for the acid fast organism, culture, and guinea pig inoculation of a centrifuged specimen of urine.

Pyogenic infection of the kidney is due to coliform organisms in 85 per cent or more of the cases. Unfortunately penicillin is not effective against these organisms. We find the coliform organisms as a rule in acid urine, which is determined by a nitrazine paper test; however, they also occur in alkaline urines. The finding of motile bacilli in an acid urine calls for use of a sulfa drug rather than penicillin. Culture of urine obtained through ureteral catheters, when the bladder urine is infected, frequently gives us false positives, owing to contamination of the ureteral catheter from the infected bladder urine. Also, culture of urine may give us false negatives, for the reason that some organisms do not grow, possibly as a result of exposure to high or low temperatures

or to recent use of urinary antiseptics. For determining the presence of organisms a methylene blue stain has far greater accuracy than culture of urine, although both should be considered in every case.

Malignant Cell Test.—Urine also may be searched by stain for malignant cells, after the principles of Papanicolaou² and Marshall. This requires the services of a pathologist, and a negative diagnosis is given no consideration, there must be an accurate positive finding to be of diagnostic value. Specimens of urine for staining by the pathologist should be obtained with ureteral catheters.

Recently Foot and Papanicolaou³ have presented an interesting case, a carcinoma *in situ*, of the renal pelvis and collecting tubules that was invisible on gross inspection, even after the kidney had been surgically removed. Preoperative ureteral catheter washing smears from this kidney showed "cancerous elements," and "microscopic examination of the organ revealed small areas—in which there was unmistakable evidence of carcinomatous changes in the calyceal epithelium and that of many of the collecting tubules as well." Pyclograms were doubtful—blood was seen spurting from the involved kidney. This case is favorable evidence and we can hope for development in this method of diagnosis.

4. RECTAL EXAMINATION

Rectal examination should always be carried out after the voided urine, in the male, has been obtained. Otherwise palpation of the prostate, after a light massage only sufficient to obtain prostatic fluid for examination, will be accountable for microscopic blood found in the urine. In the female a perineal examination is made for urethro-cysto-rectocele, one or all, which might account for a bladder residual urine causing infection and subsequent hemorrhage. A caruncle could cause bleeding at the urethral meatus. All of these determinations for the source of infection, or for the source of bleeding, in our step-by-step analysis bring us closer to the final diagnosis which, even with complications in the lower urinary tract, may still be cancer of the kidney. We must rule out the more frequent sources first, always referring back to the patient's history for the "first symptom, when and where."

5. RESIDUAL URINE

As hematuria or urinary infection may be the "ushering in" symptom of urinary cancer, and as we are considering cancer of the kidney, we lean rather heavily on the duration of symptoms of the bladder, as secondary to symptoms localized in the kidney region.

It is important to have an established method for obtaining a bladder residual urine. We must recall that each kidney can excrete as much as 30 cc. of urine in a minute, particularly when the individual has been drinking large amounts of fluid. It is also necessary to recall that many persons have a psychic inability to empty the bladder under stress—the

stress may be due to nothing more than being in the doctor's office; anticipating intrusion, for example. The patient should be assured that he will not be molested, and asked to empty the bladder completely. He or she when finished must notify the doctor or nurse immediately, who should catheterize within two or three minutes after the bladder has been emptied. Such a test for residual urine is not important in the diagnosis when there is a large mass in the kidney region, at least in respect to the involved kidney, but it may be important in evaluating the function of the kidney that is to remain after nephrectomy for tumor, and in revealing a permanent pool of infected urine.

6. X-RAY EXAMINATION OF THE URINARY TRACT

K.U.B. Film.—The x-ray study should, in every instance, include first a plain or scout K. U. B. film (K. U. B.—kidney, ureter, bladder). Films of the urinary tract are best in size 14 by 17 inches, and should include the entire kidney and the symphysis pubis. If a scout film should be omitted, calcification within a kidney tumor, or stone complicating the involved kidney or the *opposite kidney* may be missed, as after either the intravenous injection or retrograde injection of pyelographic fluid such calcification may be concealed by the radiopaque fluid (iodine).

Excretory or "Intravenous" Pyelography.—Excretory pyelography probably fails to provide a surgically diagnostic film of the *kidney cancer* in 50 per cent or more of all cases. The limited value of this procedure, as compared with retrograde pyelography, is due to the fact that the amount of iodine which reaches the kidney through the blood stream, to be excreted into the pelvis, is less than that which reaches the kidney when the solution is injected through a ureteral catheter. An x-ray diagnosis of early cancer of the kidney, as well as late cancer in many instances, requires a sharp outline of the kidney pelvis. This is best obtained with the heavier concentration of iodine contained in the pyelographic fluid used with the retrograde (cystoscopic) procedure.

In obese or muscular people it is usually necessary to supplement intravenous pyelography with the retrograde type, as the pelvis of the kidney shows in outline only as its density exceeds the density of the patient's body. Also it is true that in the intravenous pyelogram the kidney pelvis is not overdistended as it frequently is in retrograde pyelograms. Overdistention of the normally elastic kidney pelvis may bring out the invasion of an inelastic tumor extending into that pelvis. Also, in the small kidney pelvises of children and in the deeply intrarenal "spider-leg" type pelvises of adults, through which excretion is rapid, systoles and diastoles of contraction occur simultaneously and may involve different, long or narrow, minor or major calyces; we then may have a poor visualization of calyces, squeezed by these emptying contraction systoles. Such areas often strongly suggest the filling defect of tumor. However, frequently the areas simulating filling defects will not appear in all films, which is a valid reason for a plain film, five minute film,

fifteen minute, and two thirty minute films; of the last, one is taken with the patient flat and the second with the patient erect to show kidney mobility and another angle view of the kidney pelvis: it is taken immediately after voiding to show a remaining residual bladder urine, as well as the low ureter, which may otherwise be obscured by a full bladder, dense with radiopaque fluid.

A general rule is imperative in analyzing the intravenous pyelogram, particularly for diagnosing early cancer of the kidney. *No pyelogram showing imperfectly filled or poorly visualized calyces should be accepted as evidence for or against the presence of cancer of the kidney.*

In spite of its drawbacks, excretory pyelography may be of great service in the diagnosis of cancer of the kidney. In the order of their importance I should like to list the possible benefits as follows:

(a) The obtaining of an excellent pyelogram, in children and suitable adult subjects, when not of the involved kidney particularly, then of the opposite kidney, makes ureteral catheterization unnecessary.

(b) It may corroborate kidney pelvic distortion or filling defect found by retrograde (cystoscopic) pyelograms.

(c) It aids in determining a changing (location, shape, and size) filling defect, such as blood clots or stones. Such stones may be faintly radiopaque.

(d) It shows the renal substance more plainly than a plain or scout kidney-ureter-bladder film. This may be, but usually is not, diagnostic in itself. However, it is an interesting point.

(e) It serves as a test of kidney function. In cancer of the kidney this has variable value. A small cancer may not alter the ability of the kidney to excrete iodine, and a sizeable, though not huge, carcinoma of the kidney may so increase the vascularity of the kidney that its ability to excrete iodine may increase. It shows function of the opposite kidney, which is to remain after nephrectomy. The film taken five minutes after injection of the pyelographic fluid should show some iodine in its pelvis, if it be normal in excretory function.

It may be considered clinically that injury to a kidney causes it to fail in its function, first, in its ability to excrete dye (phenolsulfonephthalein, or indigo carmine), secondly, in its ability to excrete electrolytes, urea and the like, in which category we place iodine, and lastly, in its ability to excrete water. A patient may live almost indefinitely, provided the kidney impairment is not progressive, and yet have no, or very poor dye excretion. The dye excretion test is carried out at cystoscopic examination, obtaining the differential dye excretion of the two

concentration of the dye are fraught with many errors, not in the dye itself, but in the collection of the urine. In particular the urine may be held up, back of the catheter, and come down the side of the catheter

into the bladder, or the ureteral catheter may cause a spasm, obstructing the ureter, which in a few minutes might interfere with dye excretion function of that kidney. For these reasons it is often considered that the time of appearance and the concentration of dye from each of the two kidneys, as viewed by the examining physician, are best reported at the time of examination, in preference to writing down colorimetric figures which may be erroneous and may mislead a future observer in assessing the accuracy of the test.

When both kidneys fail in their ability to excrete electrolytes, we anticipate a rise in the blood nonprotein nitrogen (uremia). When further kidney damage renders water excretion imperfect, fluids accumulate in body tissues and cavities.

(f) Certain bifid type kidney pelvis⁴ and ureters may be found by the intravenous pyelogram when the retrograde pyelogram does not show filling of one of the bifid portions. This advantage may be important in the diagnosis of cancer of the kidney, especially when either an upper or lower major calyx is not filled. This failure to fill in retrograde pyelography may be due to the calyx joining the ureter within the kidney pelvis. It seems in these instances that the pelvis, overdistended by filling, closes off the small pelvic opening of certain of these upper or lower major calyces, usually the upper. Such unfilled calyces join the pelvis by a long, narrow infundibulum. This means that the hilum of the kidney is abnormally situated, either unusually high or low, in its location on the inner surface of the kidney.

With infants, following the scout or plain film, frequently the best intravenous pyelogram is obtained three minutes after the intravenous injection. Subsequent films should be made every three to five minutes, until the maximum filling and visualization of the kidney pelvis has been accomplished. The bladder then will show an opacity in outline and density suggesting that excretion of the intravenous urographic medium, in large part at least, has been accomplished.

In both infants and adults it is well to dehydrate the patient by omitting fluids and food for twelve hours before intravenous pyelography. Also it is well to empty the bowel as completely as possible just before the procedure, as gas in the bowel frequently obscures the pelvis. Gas creates a negative shadow, which, when overlying the pelvis, causes a false filling defect, or it may completely obscure the entire pelvis.

Pressure on the lower abdomen should not be routinely used, as it may compress and thus obscure the low ureter, and it may falsely dilate the upper ureter. When it is used, the balsa wood ball or the abdominal band should be applied after the fifteen minute film, with the patient in Trendelenburg position. Many urologists prefer to use the Trendelenburg position only when taking the last two (thirty minute) films. Also "delayed films" are of value. When the excretion of the iodine is slow in intravenous pyelography, it may be helpful to take films one, two, four and even twenty-four hours after the scout film and the intravenous injection.

Immediately after the thirty minute flat film is taken an erect thirty

minute film is made. This erect film not only adds one more film for study, but because the relationship of the kidney to the bowel, calcified lymph gland and any extrarenal artifact is changed, it provides additional data on filling defects, blood clots, stones, and gas in the bowel. Renal tumor mass obviously retains an unaltered relative position to the kidney pelvis, no matter what the position of that kidney may be.

(g) Intravenous pyelography is accomplished rather easily from the patient's standpoint. When the films are clear, well filled, and *normal*, they relieve the patient of the necessity for retrograde pyelography of one of one or both kidneys.

Retrograde Urography—Cystoscopic Examination.—Cystoscopic examination with ureteral catheterization is indicated in all urological cases to determine the inciting cause of a pyelonephritis, hematuria, or kidney pain that is not clearly evident from a well filled, sharply outlined intravenous pyelogram and cystoscopic examination of the bladder. Since the advent of sulfanilamide and the antibiotics (penicillin and streptomycin), this important fact is overlooked at times. Unfortunate, indeed, is the early cancer patient whose resultant first infection, hemorrhage or pain is controlled by these drugs (and cystoscopy delayed) through the period when nephrectomy would offer a favorable prospect of cure. Analysis of the symptoms, as outlined under "History," may point to the kidney, particularly if the blood clots in their ureteral passage cause pain. However, when this is not the case, and should the patient show no bladder residual urine, and the infection or bleeding persist, kidney investigation, with ureteral catheterization, should be carried out. Whenever there is an infected residual urine intravenous pyelography is preferred at first to retrograde pyelography, or a sulfa drug may be given for twenty-four hours, and then retrograde pyelography may be carried out without too much danger of inciting a kidney infection by passing ureteral catheters through the infected bladder urine into a renal pelvis which is possibly not infected.

Renal pain may occur as a result of regurgitation of bladder urine through an open ureteral orifice up the ureter to the kidney pelvis. If the pain subsides after filling the bladder with a 15 per cent solution of sodium bromide or sodium iodide this point will have been demonstrated. Whenever, upon cystoscopic examination, no pathologic change is found in the bladder other than a mild cystitis and the ureteral orifices are normal, and there is no residual urine, it is advisable to make differential methylene blue stains of the kidney urine, differential kidney phenolsulfonephthalein tests, and last, retrograde pyelograms. Methylene blue stains for the presence of organisms and pus cells in the right and left kidney urine specimens are more reliable than culture—particularly if the bladder urine is infected—frequently the ends of the right—

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cystoscopic held—as a

result of slight trauma of the ureteral catheter or the accidental rupture of a small surface mucosal vessel. Gross blood, while at times suggestive of cancer, is also due in a large percentage of cases to the passage of the ureteral catheter, particularly when the same amount of bleeding was not present just before its passage. On the other hand, it is possible for the ureteral catheter to meet with a ureteral tumor or a pelvic tumor which would bleed freely. Bloody urine spurting from a ureteral orifice at cystoscopic examination, and before ureteral catheterization, points strongly to early cancer of the kidney. When it is seen at the time of retrograde pyelography, and the pyelograms are normal, it calls for continued observation until the exact source of the blood is determined, or until sufficient time (several years) has elapsed to prove the improbability of the existence of cancer.

Inflammatory changes in the papilla of a kidney, or congenital, superficial dilated blood vessels on the papilla or pelvis can bleed without the presence of infection, and without tumor being present. These instances are *extremely rare*, and probably are seen no more than once or twice in the lifetime of a busy urologist.

Retrograde pyelograms in search for early cancer of the kidney must be made with a solution that makes a sharp outline, even of the smallest minor calyx. For this the pelvis must be well filled, slightly distended, which in turn suggests a slow filling of the pelvis through the ureteral catheter. By maintaining thumb pressure upon the bulb of the ureteral catheter syringe, and noting the degree of this thumb pressure, which can be recognized by using the very tip of the thumb to direct the amount of pressure, thus having nailed sensitivity, we can recognize the increasing intrapelvic pressure and therefore not produce marked over distention. The overdistended pelvis can cause kidney colic, and also force the pyelographic medium into the renal substance and its blood vessels, which may obscure the outline of the kidney pelvis.

Interpretation of Pyelograms in Early or in Late Cancer of the Kidney.—Various parts of the kidney pelvis, calyces and ureters are simultaneous in emptying or filling phases. These phases are spoken of as systole and diastole, as mentioned under "Intravenous Pyelograms," but it is well to recognize that manual or thumb pressure overfilling through ureteral catheters stops these phases entirely. The pelvis is overdistended and at rest while overdistended. Occasionally in retrograde pyelography a small bolus of air is injected; it is usually easily recognizable as it changes position, and in addition its spherical shape is too perfect to be mistaken for pathologic change.

It is not necessary to withhold the intake of fluids before retrograde pyelography, but it is advisable to give at least one high enema to expel gas just before the picture is taken. When visualization of the low ureter is desired, it is sometimes wise to pass a rectal tube while the patient is on the cystoscopic table, and relieve the lower bowel of a large bubble of gas, and to have him void before the last thirty minute (erect) film.

Retrograde pyelograms, similarly to intravenous pyelograms, are best

taken on 14 by 17 inch x-ray films. The scout film is always taken first. Following the scout film, one filling of the pelvis is carried out with the patient in a flat position. It is well to leave the ureteral catheters in until this pyelogram has been developed and known to be satisfactory. Then the kidney pelvis are again injected and the patient raised into an erect position. Injection of the pyelographic fluid is then continued as the catheters are withdrawn, thus obtaining ureterograms as well as pyelograms.

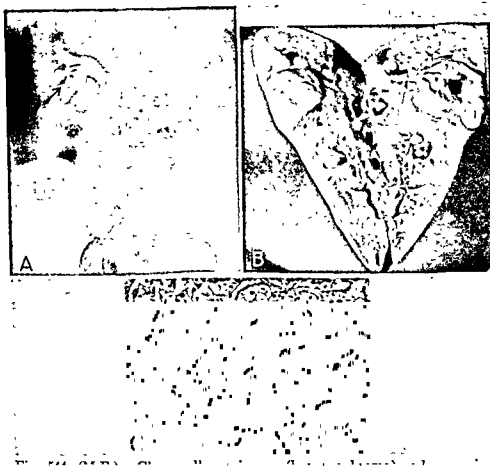
The large, clear cell carcinoma (hypernephroma) frequently is round, and so occasionally is difficult to differentiate from a malignant cyst or large benign solitary cyst. The former is encapsulated until quite late in its development. There is, however, a distinct difference in its pyelographic appearance in the large majority of cases owing to the fact that the solitary cyst presses only, while the capsule of the clear-celled tumor (hypernephroma) fixes the pelvis or calyx, therefore widening, as well as elongating, the involved calyx, thus shading the line of the filling defect. The solitary cyst, on the other hand, frequently produces a fine sharp line in its filling defect. In early or late carcinoma of the kidney we see displacement, obliteration, elongation of pelvis and calyces, in addition to invasion, with marked distortion. Occasionally calcification within the tumor is found. *Alteration of the kidney pelvis in any manner is relatively easy of interpretation in the large, or late cancer of the kidney, it is in the early malignant condition, ushered in by occult blood in the urine found at a routine examination, by the first gross hematuria, or by the first evidence of a urinary infection, that we have to repeat our pyelograms.* Hence, the two pyelograms by the retrograde and the four by the intravenous methods may be required to establish the diagnosis of any early filling defect, or a pathological deviation in the outline of the calyx, or the displacement of a minor calyx. When this point has been established, then a summary of our complete method of diagnosis, *accumulating the positive findings*, will determine whether immediate surgical intervention or further observation is indicated.

When hematuria persists, blood clots can be confusing, particularly in the interpretation of filling defects. It is true that blood clots change their shape, size and location in repeat pyelograms, however, when they are numerous these changes cannot be accurately evaluated, as is possible in the case of a single clot. Here the intravenous pyelogram is of great value, for even though repeat pictures are not entirely clear in all instances, they will point out the constant filling defect.

Figure 544 brings out such an abnormality. The constant abnormality in this case is the short, straight line, a compressed calyx marked by an arrow, about which there is a confusion of filling defects. The filling defects are partly filling the kidney pelvis.

...very, and
...with a cortical solitary cyst

Nephrectomy was performed five days after the initial hemorrhage. No mass was palpable. Pain was present due to the passage of blood clots down the ureter. It is interesting to note in this case that the solitary cyst, probably 4 inches in diameter, was not diagnosed at the time of pyelography; it was attached to the cortex, and had not invaded or displaced any



blood clot in center. *C*, Photomicrograph shows large clear cells with architecture of adenocarcinoma.

portion of the renal pelvis. The prognosis here is improved by obtaining the one persistent pyelographic distortion of the pelvis in the face of continuous bleeding, and so enabling us to operate without delay, rather than waiting for the hemorrhage to cease. This is a fine example of the value of combining the two methods of x-ray diagnosis.

Aortography.—This procedure^{6, 7} promises to be an advance in x-ray diagnosis of renal disease. As yet its value is not established; its use requires not only a surgeon but an anesthetist, in addition to the roentgenologist. A danger accompanies the procedure. It is doubtful that it has

present value in routinely diagnosing tumors of the kidney. It is also doubtful that its diagnostic value will equal its dangers except in certain instances. It may be that its use will be of value in diagnosing early cancer of the kidney, and ruling out aneurysm of the renal artery, which could be confused with a tumor of the renal hilum, or in difficult cases it may supplement intravenous or retrograde pyelography.

The procedure is carried out with the patient supine and as a rule anesthetized with pentothal sodium. A 15 cm. needle is passed into the aorta, through a skin puncture at a point $3\frac{1}{2}$ to 4 inches anterior to the spinous process immediately below the twelfth rib. Occasionally this point is established one vertebra lower. Twelve and one-half cubic centimeters of 80 per cent sodium iodide are injected into the aorta, to flow on through the renal blood vessels, abnormalities of which are interpreted in x-ray films which show the iodine in circulation. The latest literature should be reviewed before attempting aortography. At first practice should either be carried out with an anatomical specimen, or the surgeon should be assisted by one trained in the procedure.

Perirenal Air Insufflation.⁴—This procedure has its greatest value in outlining a retroperitoneal mass in the kidney region which cannot be demonstrated by other x-ray procedures. Kidney tumors may extend outward from their cortical origin and not invade the renal pelvis until late in their development.

Perirenal air insufflation is of particular value when "masculinity" changes suggest a tumor of the adrenal cortex; or hypertensive changes suggest a tumor arising from the medullary portion of the adrenal gland. The principle is to create, by injecting air or oxygen into the perirenal space, such a marked difference in density that an irregularity in the normal contour of the kidney shadow, or a mass in the upper renal region, will show even though the adrenal tumor be small. Dangers which are entailed in the procedure are sufficient to preclude its general use at the present time. A sudden drop in systolic blood pressure, evidently reflex from the change in the retroperitoneal pressure, may result in death. Such a deplorable outcome, however, is preventable by having the patient breathe oxygen continuously. The needle is inserted into the back, and when it reaches this area respiratory

movements of the needle are noted. Aspiration is then carried out to be sure that the point of the needle is not in the kidney substance or in a blood vessel. Saline solution next is injected to further help locate the point of the needle in the perirenal space and to separate it from the kidney capsule. Following this 600 to 900 cc. of air or oxygen are injected. Again, the beginner should be assisted by one experienced in the procedure, and after obtaining the most recent information in current medical literature.

CLASSIFICATION OF KIDNEY TUMORS¹⁰

Benign Tumors.—In diagnosing cancers of the kidney we must consider all large or small benign tumors of the kidney, as well as all masses,

located near the kidney region which could be either extrarenal entirely, or superficially or typically connected with the kidney. In this category are adrenal tumors, retroperitoneal sarcoma, solitary cyst of the kidney, multiple cysts of the kidney, liver, spleen or pancreas, enlarged spleen, subcapsular hemorrhagic masses of the kidney, hydronephrotic kidneys, renal lipoma, gallbladder diseases, and rarely ovarian tumors.



Fig. 545 (A, B, C) Retroperitoneal sarcoma, retroperitoneal sarcoma, retroperitoneal sarcoma.

tumc
Stone
invol

...ous tissue, fat, infection.
...with a history of intermit-
...preoperatively could be
confused with carcinoma. Stone by plain x-ray without follow-up pyelograms
would be insufficient for diagnosis. Intravenous pyelograms showed normal left
kidney, with no function on the right. This, followed by retrograde pyelograms,
points to the necessity for nephrectomy.

Small benign tumors, such as adrenal rests (exceedingly rare) or adenomatous (benign adenoma) or fibrous and round whitish masses, usually seen through the kidney capsule, though at times spread throughout the parenchyma, are most frequently found in adults at autopsy; much less frequently are they found in children.

Among the larger benign tumors, and those requiring surgical intervention for differentiation, are lipomas, which may be replacement masses of fat usually involving the hilum of the kidney (Fig. 545). They are replace-

ment in that destroyed kidney tissue is replaced by fat; sarcoma may be associated. Also, at times, the fatty capsule of the kidney is markedly increased; again one must make sure that such a tumor is not liposarcoma. Small subcapsular discreet fatty masses are true lipoma—they usually are multiple.

Malignant Tumors.—Age Incidence.—As tumors of all classifications may occur at any age, we cannot preoperatively allow statistics to influence our surgical judgment. Probably 75 per cent of Wilms' tumors occur before the fifth or sixth year of life; however, they also occur during senility. Cancer of the renal parenchyma is most frequent in the fifth and sixth decades of life; however, they also occur in childhood.

TUMORS OF RENAL PARENCHYMA.—Wilms' tumor contains cancer cells of mesothelial and epithelial origin, and thus is an adenomyosarcoma. It is highly malignant. It is often found in infants and children at routine examination, and usually, particularly in infants, by bimanual palpation of the kidney region. For early diagnosis this type of palpation should be carried out by all pediatricians at every routine examination. Frequently there is no associated hematuria or pain. Diagnosis is accomplished by intravenous pyelography, primarily to demonstrate a normal opposite kidney, and then usually by one kidney retrograde pyelography to visualize the pelvis of the involved side. The tumor at first is encapsulated, and therefore the pyelogram at such time shows the calyces than invasion. It is a

of mixed epithelial and mesothelial origin) much more frequently we have arising from renal parenchyma the adenocarcinoma of epithelial origin, which may be divided into clear and granular cell cancers. Frequently the two types of cells are found in the same cancer. The chief point of interest is that the hypernephroma is a clear cell tumor, and when distinguishable as a pathological entity it is

tumor

cells of

by way of the blood stream. The renal vein and vena cava may be opened at surgery for removal of such an advancing plug of tumor. A typical tumor of this type is less malignant than the sclerotic granular cell tumor which spreads in all manners—blood, lymphatic system and direct extension—and often shows dense tongues of fibrous tissue advancing between masses of cancer cells, arranged in any architecture or formation.

The adenocarcinoma varies in microscopic architecture: adenomatous (glandular-like structure), alveolar (with open spaces), papillary and mixed. A papillary adenocarcinoma, a term used to describe a hypernephroma,¹¹ is obviously of mixed architecture. An adenocarcinoma in microscopic section may be typically clear cell (hypernephroma) in one area, with other areas of granular cell and of mixed architecture. The

gross hypernephroma seems to be an entity as described, but doubt on this point certainly exists. (Figs. 547 and 548.)

Tumors of the kidney of connective tissue origin (renal parenchyma or its pelvis) are *sarcoma* and *liposarcoma*. These tumors are infrequent—rarely a benign smooth muscle tumor, *leiomyosarcoma*, is reported.

TUMORS OF THE RENAL PELVIS.—Cancers of the kidney pelvis (calyces, pelvis and ureter) are chiefly of epithelial origin. They may be

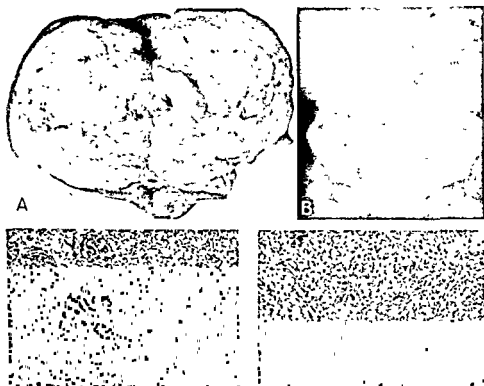


Fig. 546 (D. M.).—Wilms' tumor in a 19 month old male. Mass in right flank found by pediatrician on routine examination, at which time no illness was suspected. A, Tumor removed; large, soft, gray mass, fairly well encapsulated. B, Intravenous pyelogram shows a hazy left normal pelvis, right pelvis markedly distorted. Retrograde pyelograms not carried out, being considered unnecessary with the mass present. C, D, Photomicrographs of mixed tumor arising from mesothelial and epithelial tissue. Renal tubules suggested (C), and markedly undifferentiated tumor (D).

benign papilloma, or the exceedingly malignant *squamous cell carcinoma* of the kidney pelvis, or the *alveolar carcinoma*. The warty benign papilloma becomes malignant or not—but if or when it does, its base or separate fronds may show different degrees of malignancy. During the stage of its growth as a malignant papilloma, early and complete removal by surgery is hopeful. Later as an alveolar carcinoma it offers in almost hopeless prognosis, as it spreads rapidly by vascular and lymphatic systems, but chiefly by direct extension.

The firm or indurated squamous cell carcinoma of the kidney pelvis, often showing characteristic pearls and cornified areas, is still more

begins. In this manner a flap of the abdominal wall attached along the anterior margin of the thorax can be turned back. The resultant exposure is excellent.



1. Transitional cell (papillary) carcinoma of renal pelvis. The important point in this case of papillary carcinoma of the renal pelvis is the fact that the patient for three months had been given the diagnosis and observed for benign prostatic hypertrophy before being referred for urological diagnosis. The reason for this was that the patient alone saw the hematuria, and could not decide whether the blood was passed at the beginning (initial) or at the finish (terminal) of urination. A two-glass test would have cleared up this point, and so gained him a three months earlier diagnosis. A, Pyelogram by retrograde method shows distortion, fixation and invasion of the right side, with left kidney normal. B, Papillary carcinoma of the renal pelvis and ureter is seen in the specimen removed by nephro-ureterectomy through an extended loin incision. C, Transitional cell cancer of the renal pelvis, grade II.

An oblique loin or kidney incision is made with the patient on his side—in "kidney position"—a kidney rest elevating and rendering taut the side or loin to be operated upon, and with the arm and leg of that side extended to make further tension at the site of incision. If this incision is found inadequate the patient may be rolled back 30 to 40 degrees from

the lateral position, and the second incision then carried upward along the border of the abdominal rectus muscle as necessary to give full free vascular renal pedicle exposure—so that it may be tied before manipulation of the kidney.

Nephroureterectomy may be performed as a single or two stage procedure. In either instance, after the ureter-bladder junction has been



Fig 550 (H. P).—Transitional cell (papillary) carcinoma, of renal pelvis
 A 54 year old white man had renal colic one and one-half years prior to admission to Barnes Hospital. No other urinary symptoms occurred in the interval. A, the left renal pelvis, right the upper ureter was con- ureterectomy was done four days later, removing the ureter down to and including the ureteral orifice in the bladder. Of course, deep x-ray therapy followed. B, Specimen removed at nephrectomy. C, Transitional cell carcinoma of the renal pelvis, grade I.

identified, pulling lightly upon the ureter will in effect pull outwardly the amount of bladder that should be removed with the lower ureter.

If the kidney tumor unfortunately is large when the patient first presents himself for surgery it should be removed and postoperatively the patient should be given *x-ray high voltage therapy*. This course is

preferable to delaying nephrectomy or nephroureterectomy for the purpose of shrinkage and possibly *easier surgery*

GRADES OF MALIGNANCY

Grading of all kidney tumors is of value after their removal, as it accumulates evidence for us upon which to classify cancer as to prognosis and estimate the benefits of postoperative irradiation. Broder's index or classification¹² is based on the evidence that the well differentiated cancer cell is less malignant than the less differentiated cancer cell. His grading is from grade I to IV, the figures directly giving index to an increasingly large percentage of malignant (less well differentiated) cancer cells. The grade does not make possible an immediate or specifically individual prognosis in cancer of the kidney—all grades are cancer.

Dr Lauren V. Ackerman, Associate Professor of Surgical Pathology, Washington University School of Medicine, has kindly furnished the following statements regarding the grading of cancers of the kidney:

Carcinomas of the renal pelvis and ureter are usually of the transitional cell type. These tumors, like the tumors of the bladder, can be graded, and in a large group this grading will be of value from the prognostic standpoint. In a large series a high proportion will be well differentiated.

Grade I would consist of tumors with well defined arborescent branching with connective tissue stalks supporting the tumors, and with uniform, closely adherent cells usually without mitotic figures and with an even pattern.

In Grade II, the fibrous strands would tend to include large groups of cells. Mitotic figures would be more abundant but the pattern would still be well defined.

In Grade III the tumor would begin to break up, lose its cohesive qualities, and the cytoplasm would decrease in amount. The nuclei would become more prominent and the chromatin denser. Mitotic figures would be even more abundant.

Finally, in Grade IV, the tumor would be completely anaplastic and individual cells would be growing in small nests, but their transitional cell origin could be recognized by the fact that their nuclei would be very dense and homogenous. The cytoplasm in individual cells would be small in amount.

The grading of this group of tumors will be of most value when the proper treatment has been employed. The entire ureter including its intramural portion has to be removed with the main tumor, otherwise the percentage of local recurrence will be greatly increased and thereby the prognosis will be altered for the worst (Kimball¹³).

Carcinoma of the parenchyma of the kidney often presents a bewildering microscopic pattern, varying from one area to another. Grading of these tumors will be of very little, if any, value in prognosis. It is much more important to pay particular attention to the invasion of the renal veins at the hilum and invasion of veins through the capsule of the kidney. The presence or absence of vein invasion will be a primary factor in prognosis (McDonald¹⁴).

Finally, in a group of carcinomas of the kidney, the larger the tumor, the higher the percentage of metastases (Bell¹⁵). Naturally, there are exceptions to this rule. Small tumors measuring no more than a couple of centimeters may metastasize widely, and large tumors of long duration may remain localized.

SUMMARY

Cancer of the kidney must be diagnosed early in its growth, while it is a localized disease, if we are to expect favorable results with and after nephrectomy. A method, an analytical diagnostic procedure, is presented which will enable us to make an early diagnosis of cancer of the kidney. It is to be followed, step by step, to the point of establishing the origin of urinary infection, hematuria or pain, when any of these symptoms are first noted by the patient or physician. Recent advances in the diagnosis of cancer of the kidney are discussed.

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ADVANCES IN MANAGEMENT OF PROSTATIC DISEASE

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In general, surveys of results following prostatic operations have shown a gratifying fall in mortality rates in the last few decades. A recent study of mortality following all prostatic operations for benign hypertrophy performed in Bellevue Hospital¹ during the years from 1920 to 1946 shows a fall from approximately 40 per cent in the early years to 4.6 per cent in 1946. This decrease in mortality rate is in large part a reflection of improvements in surgery generally, with increased understanding of the physiology of the aged, more adequate treatment of shock, chemotherapy, and other factors. Specific urologic advances have also contributed to the improved picture. Some of the more recent changes and improvements in this field will be reviewed in this paper.

ANATOMIC AND PHYSIOLOGIC CONSIDERATIONS

"Lobes" of the Prostate.—Any discussion of prostatism necessarily involves mention of the "lobes" of the prostate. We speak of lateral, median, anterior and posterior lobes, yet from the standpoint of normal human anatomy, both gross and microscopic, there seems to be little justification for dividing the prostate into lobes at all. Nevertheless, the behavior of the human prostate in disease justifies some sort of division. It is recognized that the condition of benign prostatic hyperplasia arises in the prostatic tissue situated nearest to and surrounding the urethra in the anterior portion of the prostate. Hyperplastic nodules appear in this location and grow to large lobular masses. In growth they displace and compress the more peripheral prostatic tissue which thus forms a sort of capsule about them. The compressed prostatic tissue about the adenomatous lobes is the "surgical capsule" within which the operation of prostatectomy—more correctly enucleation of nodules—is ordinarily done for benign prostatic obstruction. Carcinoma of the prostate, on the other hand, is known to arise characteristically in the posterior areas of the prostate nearer the rectum and relatively distant from the urethra.

In the normal prostate of man, Huggins² has now described an interesting differentiation between the anterior periurethral and the posterior prostate. He has indicated, by experiment, that the response of these two portions of the prostate to estrogens differs even in the normal gland. After estrogen administration a fairly clear-cut division between the

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anterior three-fourths and the posterior one-fourth of the prostate can be demonstrated histologically. This and other observations lead Huggins to postulate that the human prostate, in common with that of many other species, is not a homogeneous organ but is in fact a double gland consisting of a larger anterior and a smaller posterior prostate.

Phosphatase.—Despite an awakened interest in the physiology of the prostate gland in recent years, understanding of its functions is very imperfect. At the present time the only known function in humans is that of contributing an enzyme to the semen that results in its liquefaction. Other enzymes also are known to occur in normal prostatic fluid. One of these—a phosphatase—has assumed importance in recent years in connection with carcinoma arising in the prostate. The normal prostatic epithelium elaborates this enzyme and contributes it to the prostatic fluid in enormous quantities. The prostatic phosphatase is of a peculiar variety. The phosphatase produced in other parts of the body functions as a catalyst to split organic phosphates in a medium that must be alkaline, whereas prostatic phosphatase works in an acid medium and thus is called “acid phosphatase.” It has been found that not only does normal prostatic epithelium produce this substance, but often carcinoma cells derived from prostatic epithelium continue to elaborate acid phosphatase, even when they have metastasized. In this case, the elaborated

prostate

PREOPERATIVE MANAGEMENT OF URINARY RETENTION

Since the purpose of this report is to highlight newer concepts, it is not intended to review completely the long-accepted principles of the care of prostatic obstruction.

Decompression of the Bladder.—The old dictum that a distended bladder must be decompressed gradually over an extended period of time has been generally abandoned. The basis upon which this idea rests has been shown to be false. Sudden decompression is no more likely to lead to hemorrhage or uremia than gradual decompression. These complications are due to infection and not to mechanical factors. In both animals and man, observations over many years have shown that if there is any difference between sudden and gradual bladder decompression it is in favor of rapid emptying.⁴

Minimum Instrumentation.—Emphasis now is being placed upon minimum preoperative instrumentation and manipulation in the case of

tion finally is performed the patient approaches it with a very complete diagnosis but completely infected as well. The routine preoperative

intravenous urogram is becoming increasingly popular, not only for discovering the frequent presence of hydronephrosis, or vesical calculi, but also to gain information regarding the type and amount of prostatic hypertrophy. The cystoscope, however, is not easily discarded. Diagnosis and determination of the best method of treatment are often inadequate without it. The plan of D. K. Rose and others⁵ in the preoperative management of urinary retention seems particularly logical. No catheterization or instrumentation of any kind is done until immediately before surgery. The patient is cystoscoped in the operating room, the best type of operation decided upon, and surgery performed forthwith.

An extreme example of minimum preoperative instrumentation is the procedure of Wilson Hey in England. On the theory that "postoperative uremia is due to infection and is encouraged by any method of slow decompression, open drainage, or instrumentation," Hey performs what he calls "aseptic prostatectomy." Diagnosis is made without the use of preoperative urethral instrumentation of any kind. Suprapubic enucleation of the adenoma is followed by retrograde introduction of a catheter into the urethra from the bladder end downward so as to minimize infecting the bladder and prostatic bed from the contaminated distal urethra. Others in England⁶ seem to be impressed by Hey's idea and enthusiastically follow his method in treating patients with acute urinary retention by such emergency operation. It would seem that the practice Hey condemns, preoperative infection by instrumentation, is offset by too much uncertainty in diagnosis.

SOME RECENT CONTRIBUTIONS TO THE TECHNIC OF OPERATIONS UPON THE PROSTATE

Transurethral Resection.—It is now conceded that, to avoid persistent postoperative infection or recurrence of obstruction, a transurethral resection should remove all adenomatous tissue. To remove a small core of periurethral tissue is no longer considered adequate. The expert strives to resect all tissue down to the prostatic capsule itself. It must be admitted that many operators fail to accomplish this end. The unsatisfactory results ensuing have made some urologists abandon resection in favor of open surgery for all but the small obstructing prostates. Recent analyses show, however, that transurethral resection is still the most popular method of operation for prostatic disease.⁷

Postresection Hemolysis.—More complete and thorough resections of the prostate have resulted in a new difficulty. Intravascular hemolysis has been shown to accompany a large proportion of transurethral resections. Experiments by Creevy⁸ suggest that this hitherto unsuspected complication results from irrigating fluid entering the general circulation. The irrigant enters the blood by way of veins opened during the resection, especially when the prostatic capsule is approached where large venous sinuses exist. Since the irrigating medium under which a resection is done must not be an electrical conductor, sterile distilled or tap water commonly has been used. If enough of such a hypotonic fluid enters the

blood, hemolysis of red cells inevitably follows. Creevy has demonstrated that considerable amounts of irrigant may in fact appear in the blood. Using 5 per cent glucose solution, he has shown

that directly after operation. With isotonic glucose, hemolysis of course does not occur. When water is used, the amount of hemolysis found has been quite variable. In a recent report from the Mayo Clinic,⁹ 6 percent of resected patients showed postoperative plasma hemoglobin levels of more than 500 mg. per 100 cc., while 70 per cent were found with levels below 100 mg. per 100 cc.

Development of intravascular hemolysis in resection is of more than academic interest. The fatal effects of massive hemolysis are well illustrated by the following case.

requently postresection hemolysis has been offered as an explanation of the cases of postresection uremia occasionally seen. There are certain objections to this explanation. Blood levels of plasma hemoglobin have as yet not been reported approaching those required experimentally to produce renal impairment. In clinical patients where hemolysis has been accompanied by uremia, other factors have regularly been present which explain the uremia as well or better than hemolysis.

Nevertheless hemolysis does occur. Undesirable reactions therefrom are to be expected—if not uremia, at least gastrointestinal symptoms. To prevent hemolysis, isotonic solutions of nonelectrolytes are now being used as irrigants in transurethral resections. Creevy uses 4 or 5 per cent glucose solution. Technical difficulties with glucose have prompted Nesbit to use an isotonic solution of glycine.

Suprapubic Prostatectomy.—Current urologic literature demonstrates that the one-time discredited suprapubic prostatectomy is still a respectable operation possessed of distinct advantages. Of all prostatic operations it remains the simplest and much the easiest to master. If for no other reason, its popularity will doubtless continue.

One-stage Operation.—Suprapubic prostatectomy is now commonly done as a one-stage procedure. Suprapubic cystostomy preliminary to actual removal of the prostate is no longer considered necessary in most cases. The result has been a shortening of the period of hospitalization and an easier enucleation of the prostate without increase in mortality.⁷

spontaneously through the urethra as soon as possible.

Hemostatics.—After the introduction of Oxycel gauze and Gelfoam, urologists were quick to seize upon these substances to minimize immediate postoperative bleeding. They have been used extensively in suprapubic prostatectomy. No complication arises from packing the

prostatic capsule with such material after enucleation. Proper application results in excellent hemostasis.

Perineal Prostatectomy.—Judging from available statistics, prostatectomy by the perineal route is not popular. The peculiar disadvantages—loss of sexual potency, rectal injury with fistula and postoperative urinary incontinence—have prevented common acceptance. On the other hand, in one respect the perineal approach is without parallel. Up to the present time this route offers the only way to remove a carcinoma by radical prostatectomy.

Semiradical Prostatectomy for Carcinoma Prevention.—Perineal prostatectomy as commonly done for benign conditions results in enucleation of the adenomatous lobes leaving the compressed prostatic tissue behind, just as in other methods of prostatectomy. It is precisely the tissue left behind in which carcinoma so frequently arises. By enlarging the usual perineal operation somewhat it is possible to do a "subtotal prostatectomy" and remove this surgical capsule as well as the hyperplastic nodules. Thus small unsuspected carcinomas already present would be removed and future occurrence of cancer prevented. Considering the extreme frequency of carcinoma of the prostate, the advantage of such a semiradical prostatectomy for benign hypertrophy cannot be dismissed lightly. Such an operation has been advocated by Marshall.¹⁰

Retropubic Prostatectomy.—Terrence Millin¹¹ of London has added a fourth operative approach to the prostate—a suprapubic, extravesical, retropubic prostatectomy. The essential difference between this operation and the old suprapubic prostatectomy lies in the point at which the urinary system is entered to attack the adenomatous gland. Whereas in the conventional suprapubic operation the urinary system is entered above the obstruction by incision of the bladder, in Millin's retropubic prostatectomy entrance is accomplished directly at the location of the obstruction by incising the anterior prostatic capsule. This allows greater visibility at the site of operation and better control of hemorrhage, as well as other operative refinements. Though Millin's first operation was done in 1945, already thousands have been performed in Europe and America.^{12, 13, 14, 15, 16}

Retropubic prostatectomy is done through an incision just above the pubis. Dissection is carried down in the space of Retzius, between the bladder and under surface of the pubis. Here the prostate is exposed on its anterior aspect. Unfortunately a large plexus of veins is located directly over the prostate in this location. Some of these vessels must be divided to reach the prostatic capsule and considerable care is necessary to prevent occasional alarming hemorrhage. With the anterior capsule of the prostate exposed a transverse incision is made through both the true capsule and the surgical capsule beneath it. The cleavage line between adenoma and surgical capsule is easily identified and the hyperplastic tissue can be enucleated without difficulty. It is now possible to inspect the prostatic cavity. Bleeding vessels within it can be ligated or fulgurated. The vesical neck is exposed and a wedge-shaped segment of the

posterior lip excised to prevent postoperative retention or stricture. Since this is all done through an incision in the prostatic capsule, the bladder remains undisturbed. Vesical calculi, if present, can usually be extracted without difficulty through the vesical neck. To complete the operation an urethral catheter is inserted and the incision in the prostatic capsule closed with a continuous catgut suture. The abdominal wall is repaired about a small drain leading to the space of Retzius. In three to eight days the urethral catheter is removed.

Suprapubic drainage of urine ordinarily does not occur at any time. Postoperative urethral incontinence is not seen because the urethral sphincter is below the field of operation and not injured. For the same reason, the sexual function after operation is good. Almost everyone who has reported any considerable number of cases operated upon by Millin's technic has been pleased with the logic of the operation, the smooth postoperative course and the late functional result. However, this operation cannot be considered an easy one, operative bleeding may be troublesome and exposure sometimes difficult.

The possibilities of this approach for radical prostatectomy in cases of carcinoma of the prostate are being explored. It appears that by this approach removal of the prostate with its true capsule, the seminal vesicles and, if necessary, the vesical neck is feasible. Anastomosis of the bladder to the distal urethra is then accomplished to restore the continuity of the urinary tract. Several reports of small series of such operations have appeared. Indeed Souttar¹⁷ in England gives a modified technic for complete removal of the prostate by the retropubic route which he uses routinely even in the absence of cancer.

CARCINOMA OF THE PROSTATE

Unfortunately early diagnosis in carcinoma of the prostate remains uncommon because symptoms are usually late in appearing. If seen early, however, a definite diagnosis of cancer often cannot be made by rectal palpation of the prostate. Although cancer ordinarily appears in that portion of the prostate near the rectum, it may first appear elsewhere in regions not accessible to palpation. In cases where a suspicious lesion has been felt but diagnosis remained in doubt, biopsy has ordinarily been done through a perineal incision. Simpler but less exact methods of biopsy have been advocated, using a needle or special trocar to remove a core of suspected tissue for histologic study. The newest and simplest procedure to obtain cytologic confirmation in doubtful cases is the examination of either urine or prostatic fluid for carcinoma cells by the Papanicolaou technic.¹⁸ Herbert and Lubin,¹⁹ using smears of prostatic fluid obtained by massage, have shown how accurate this test can be. When the smears gave positive results, carcinoma was shown regularly to be present. An occasional negative result in the presence of carcinoma was ascribed to scanty secretions of poor quality. Perhaps by the large scale use of such methods the percentage of early diagnoses, where radical operation is still possible, can be increased from the present miserable 5 per cent.

As already mentioned, in cases of cancer of the prostate where the disease has not spread beyond the capsule, *radical prostatectomy* is indicated.²⁰ In this operation the prostate, prostatic capsule and seminal vesicles are removed. In the small number of patients suitable for this operation, cure of the disease can be expected in approximately half of the patients.

Endocrine Therapy.—Without doubt one of the most stimulating advances of recent years in the therapy of prostatic disease has been the discovery that prostatic carcinoma can be suppressed temporarily by castration or estrogens. It has long been known that the normal prostate will fail to develop if deprived of male sex hormone. It was shown by Huggins^{21, 22} that carcinoma cells derived from prostatic epithelium similarly can be suppressed by deprivation of androgen.

Orchiectomy.—In cases of carcinoma of the prostate with metastasis dramatic relief of pain often appears within twenty-four hours following castration because of shrinking of the carcinoma cells and suppression of growth. Serial biopsies of accessible metastases have shown that castration produces extremely interesting regressive changes in the tumor. Similar effects have been noted in the primary tumor in the prostate itself. Occasionally bone metastases undergo profound changes that can be detected on the x-ray, with initial increase in sclerosis and gradual fading out of the lesion.

As mentioned previously, prostatic epithelium normally produces acid phosphatase. Often carcinomatous tissue, even metastatic, continues to produce this substance which can be detected in the blood. Following castration the production of acid phosphatase falls off sharply as the metastasis becomes inhibited. Serial phosphatase determinations therefore give objective evidence of the effect of castration upon the tumor besides serving as an aid in making the diagnosis initially.

In diagnosis of carcinoma, the level of acid phosphatase in the blood has distinct limitations. When it is elevated the diagnosis of prostatic cancer is almost certain. On the other hand, a normal level does not exclude carcinoma. In the absence of metastases normal levels are found. In many instances, even with extensive metastases, the blood acid phosphatase may not be increased. Perhaps such carcinomas have become more anaplastic and lost the adult function of producing this enzyme. Changes also occur in the alkaline phosphatase of the blood in metastatic cancer of the prostate. These changes are not specific for prostatic carcinoma but are due to the response on the part of the bone to the metastases within it with the marked osteoplastic reaction so commonly seen.

Following castration a favorable response is indicated by a fall in the acid phosphatase because of decreased activity of the carcinoma cells. At the same time the alkaline phosphatase often rises higher than previously. These changes in the blood phosphatase generally parallel the clinical response of the patient with decrease or complete elimination of metastatic pain.

Estrogen Administration—Shortly after the discovery that orchiectomy resulted in suppression of prostatic carcinoma, it was found that

ACUTE ARTERIAL INJURIES

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Acute injuries of major arteries have long constituted an important and serious problem because they literally threaten both life and limb and because no completely satisfactory solution to the problem has been evolved. Ideally, the objective of therapy is the control of hemorrhage and the preservation or restitution of vascular function. Essentially this means the restoration of blood flow directly through the original channel. Although under certain circumstances the viability of the part may be maintained by the secondary or collateral circulation only, the ultimate functional result in such instances is often far from satisfactory with manifestations of varying degrees of chronic circulatory deficiency. In order to achieve both viability and ultimate normal functional activity it is essential in most instances of injuries to major arteries to restore the continuity of circulation through the original channels. As emphasized previously,¹⁰ however, the attainment of this desideratum is often restricted by certain factors that either jeopardize the effects of ideal therapy or preclude its institution. Depending upon the circumstances involved these include such considerations as time-lag, practical technical difficulties, associated injuries, site and type of arterial lesion, and the possible occurrence of infection.

It has long been recognized that the time elapsing between wounding and institution of therapy is a highly important and influential factor in determining the fate of the limb no matter what form of therapy is employed. This is well exemplified by the experience with arterial wounds of the extremities among American battle casualties in World War II which showed that with increasing time-lag there was an almost straight line progression in the incidence of amputation.¹⁰ Although there is some variation in the survival time of different tissues (for example, skin has a longer survival time than muscle) to acute ischemia, there is obviously a limit to this period of ischemia beyond which viability can no longer be maintained or restored. Accurate determinations of the limits of this period in humans have been difficult to establish because of the variables involved, but clinical experience has indicated a general rather arbitrarily set limit of six to eight hours. In well controlled experiments, to which reference is made later, Miller and Welch found that the survival rate in dog's legs following restoration of circulation was 90 per cent for periods

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of ischemia ranging up to six hours, 50 per cent from twelve to eighteen hours and 20 per cent for periods of twenty-four hours or over. There occurred, however, a variable degree of disability of the limb with contracture and atrophy in those animals whose legs survived following periods of ischemia beyond twelve hours.

Associated injuries, whether they are local or remote, may also be significant. Depending upon their extent such injuries locally may further impair or even completely destroy the regional or collateral circulation, and remotely they may require priority of attention as a life-saving matter, thus necessitating postponement of ideal vascular surgery.

Still other factors which play a significant role in affecting both therapy and end result are the site and type of arterial injury. It is well known, for example, that an injury of the popliteal artery is more serious than a similar injury of the brachial, or that an injury located above the profunda branch in both the femoral and brachial arteries has more serious consequences than one located below this branch. For this reason certain vessels have been considered as critical and others as noncritical. Obviously, restorative surgical therapy has greater significance in the former than in the latter. Variations in the type of injury, including laceration with considerable loss of substance, partial or complete severance, contusion and thrombosis, compression and acute spasm, can also influence both therapy and the ultimate result. And of course surgical repair is attended with less difficulty and greater success in a small cleanly incised wound than in a lacerated wound with much loss of substance.

It is thus apparent that the nature and circumstances of the arterial injury may have a vitally significant bearing upon both the type of therapy that may be employed and the ultimate fate of the limb. They serve to illustrate some of the conditions which affect the ultimate result regardless of therapy and some of the difficulties encountered in the solution to this problem. While they must be recognized as factors which often restrict the application of ideal therapy or jeopardize its effects they need not always be accepted as ineluctable. So long as there is a reasonable chance of survival of the part, every effort should be made to apply ideal therapy designed to restore blood flow through the original channel. As will be indicated later, recent investigations and developments provide much encouragement for the more frequent and successful application of this form of therapy.

SURGICAL MANAGEMENT

In early or immediate treatment of arterial injuries certain well established principles essential to successful management must be observed. These principles have been fully discussed previously^{14, 15, 17} and require no further elaboration here. It suffices to say that first consideration must be given to the control of hemorrhage and then to the proper resuscitation of the patient. In this connection, because of its significance both in the treatment of the vascular injury as well as in the proper

resuscitation of the patient, it is desirable to emphasize the extent of blood loss which is often considerable.¹⁰ Owing to the reduction in circulating blood volume, there is reduction in the amount of blood flow through the peripheral vessels. As a consequence the circulation of the part distal to the vascular injury may be even further impaired. Prompt restoration of the circulating blood volume and hemoglobin concentration is therefore particularly important under these circumstances.

Ligation.—As observed above, under certain conditions ligation may be the indicated procedure either because of stern necessity or because the injury involves one of the smaller noncritical vessels. In such instances it should not be done by ligation in continuity but by placing nonabsorbable ligatures well above and below the site of injury, with excision of the intervening damaged segment in order to eliminate the dangers of secondary hemorrhage, thrombosis, and vasoconstrictor influences. Ligation at a level to avoid the creation of a blind pouch may be theoretically desirable^{20, 30, 43} but the deliberate effort to do so may require extensive dissection which might further jeopardize the circulation of the part. If the concomitant vein is also injured, it should be similarly ligated, but if not, it should not be disturbed.

The deliberate ligation of the concomitant vein for the purpose of improving the circulation of the part has been the subject of much controversial discussion since Makins proposed it in World War I. This matter was thoroughly reviewed recently by DeBakey and Simeone who concluded that on the basis of conflicting experimental observations as well as on the basis of both Makins' figures for World War I and the American figures for World War II, the procedure "furnishes no protection whatsoever against the development of gangrene after acute arterial occlusion and ligation in battle casualties." More recently Simeone and his co-workers⁴⁹ have shown experimentally that vein ligation, if anything, further impairs the circulation of the part.

Repair.—As emphasized above, the ideal objective of therapy in arterial injury is the restoration of the flow of blood through the original channel. This desideratum has long been realized and the long history of arterial reconstruction and repair reflects the determined efforts that have been made toward its attainment. Excellent historical resumé of these contributions may be found in a number of publications.^{13, 21, 35, 36, 53} Fundamentally, the principles underlying most of these methods of vascular repair are essentially similar, except possibly for certain refinements in suture material or in prosthetic devices. Depending upon the nature of the injury they consist of direct suture repair, end-to-end anastomosis by suture or prosthetic devices, and the bridging of defects by vascular grafts or prosthetic tubes. No effort will be made here to discuss the advantages and disadvantages of these various methods since this has been repeatedly done elsewhere. Because accumulated experience and recent developments point toward suture repair and vascular grafts as the methods of choice, primary consideration will be given them here.

In arterial injuries in which there is little or no loss of substance,

such as small longitudinal or oblique wounds or incomplete transections, especially of the larger arteries, direct suture repair is usually indicated and may be performed with relative facility. Unfortunately, however, this type of lesion is only occasionally observed. More commonly the injury is of such nature that there is a varying amount of loss of substance which often either precludes approximation or permits it only with so much tension against the suture line that the chances of successful repair are considerably jeopardized. For this reason some means of bridging the defect must often be employed.

Principles of Suture Repair—The essential principles of suture repair are now well established, they include (1) provisional hemostasis, (2) the use of fine needles and silk, (3) accurate approximation of the intima, (4) gentle handling of tissues and maintaining their moisture, and (5) scrupulous avoidance and control of infection. Provisional hemostasis may be obtained, after exposure and isolation of the injured vessel, by the use of small rubber-shod spring artery clamps or soft rubber tubes placed snugly around the vessel above and below the site of the wound. Careful removal of all traumatized tissue and blood clots with excision of ragged overhanging adventitia to provide clean smooth wound edges is essential. The periodic irrigation of the structures with a 1:1000 solution of heparin in physiologic saline to prevent drying of the tissues and to facilitate the gentle cleansing of the wound and lumen of the vessel is also important. The arterial suture should consist of fine silk (5-0 or 6-0) directly attached to a fine curved needle and is available commercially in sealed tubes containing liquid petrolatum.

Various suture techniques have been used to approximate the wound edges. They may be classified into two broad categories (1) plain through-and-through sutures approximating the opposed edges while they are held in an everted position by traction sutures, and (2) the mattress suture placed so as to fix the intima in an everted position. Both of these methods may be modified to the extent of making them either interrupted or continuous. An effort to determine the comparative merits of these various methods was recently made by Shumacker and Lowenberg using controlled animal experiments. These investigators found that the mattress suture provides somewhat superior results to the plain suture with little or no difference between their employment as interrupted or continuous sutures. It would appear, therefore, both on the basis of these studies and clinical experience that the mattress suture, because it provides accurate intima-to-intima approximation and fixation of the opposed ends of the vessel, is a reliable and satisfactory method. Its use as a continuous or interrupted suture is perhaps best determined by the facility of application under different circumstances. The sutures should be placed fairly close together, about 1 mm. apart. Slight leakage may be observed following completion of the repair and removal of the hemostatic clamp. This is usually readily controlled by maintaining gentle pressure with moist gauze over the

suture line for a few minutes. Occasionally this proves ineffective and additional reinforcing sutures may be required.

These principles of the suture method of repair as applied to end-to-end anastomosis are essentially similar to those developed approximately a half a century ago by a number of investigators.^{6, 7, 13, 22} The cut ends of the vessel are brought in apposition and three stay sutures are introduced through all layers of the vessel at equidistant points of the circumference and are tied, care being taken to evert the edges and to provide intimal apposition. Gentle traction upon these stay sutures converts the contour of the arterial ends into straight triangular surfaces which facilitates the performance of the suture anastomosis. Each side of the triangle is sutured consecutively, care being taken to provide accurate apposition of the intima and eversion of the edges. If a continuous suture is employed the running suture is tied to the guy stitch as each segment of the angle is completed.

Vascular Grafts.—In order to permit restoration of vascular function in cases in which the injury is associated with such extensive loss of substance as to preclude direct anastomosis some means of bridging the gap is necessary. A number of methods have been described for this purpose including vascular grafts and prosthetic tubes using suture and nonsuture techniques with both intra- and extra-vascular aids or supporting appliances.^{4, 23, 31, 42, 51} In light of recent experience it would appear that vascular graft by suture anastomosis as described above is the most reliable method. Autografts or homografts of either veins or arteries have been described and used for this purpose.

In humans arterial autograft may be considered impractical except in unusual circumstances for it has the obvious disadvantage of endangering the circulation of the "donor" area. For this reason *venous autografts* have been usually employed. In using vein grafts it is desirable to employ a segment without valves, or, if valves are present, to place the vein between the ends of the artery with the valves facing distally. In order to avoid either tension or kinking, the vein segment should be of the exact length required to bridge the gap. Another technical consideration is that every branch, even the smallest, of the vein segment must be carefully ligated in order to prevent hemorrhage after the vein is subjected to arterial pressure.

Despite some success in the use of venous grafts, they have not proved entirely satisfactory either in their technical application or their functional performance owing in large measure to the inherent difference in the structure of arteries and veins.^{1, 32, 48, 50} For this reason and because of the obvious disadvantages of using autogenous artery grafts, efforts have been made to employ *arterial homografts*. Recent investigations directed along these lines by Gross and his co-workers¹⁷ and by Miller and Welch have produced highly encouraging results. Using aortic segments removed from donor dogs and stored in flasks containing an electrolyte solution, 1 per cent glucose, 10 per cent dog serum, and penicillin and streptomycin (50 units per cc.), and main-

the problem of "reflex spasm" in the large arteries. In experiments upon cats and rabbits these investigators made direct observations upon the femoral artery and plethysmographic measurements of the paw following various forms of stimulation. It was found that local segmental spasm in the large arteries could be readily produced by mechanical trauma, irrespective of an intact nerve supply. Their studies failed to reveal evidence of nervous motor control of the large arteries at least in the cat and rabbit.

If it were shown that similar anatomic and physiologic conditions exist in man, then, on the basis of these observations sympathetic block would be of no value in the treatment of this form of localized traumatic arterial spasm. Clinical experience, however, has shown that in some instances a rather dramatic response follows this form of therapy in traumatic vasospasm.^{8, 14} For this reason and because the procedure is relatively simple to perform and carries little or no risk, its continued advocacy seems justifiable. Moreover, these experimental observations do not mean that sympathetic block or sympathectomy is of no value in improving the peripheral circulation of the extremity following acute vascular injuries. The rationale of the procedure under these circumstances is the production of maximum vasodilatation by interruption of vasoconstrictor impulses transmitted over sympathetic pathways to the peripheral vascular bed. These vasoconstrictor influences may or may not be excessive but their removal increases the volume of the peripheral vascular bed and thus augments the circulating blood to the part.¹¹ This has been found, both on the basis of experimental and clinical studies, to be one of the most effective methods of producing maximum increase in the blood supply of the diseased part and is, therefore, a valuable adjunct both in the early treatment of acute arterial injuries and in combating the later effects of ischemia.^{2, 3, 5, 11, 26, 28, 29, 32, 34, 44, 45, 52}

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OPEN REDUCTION AND INTERNAL FIXATION FOR FRACTURES OF THE TIBIA AND ANKLE

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The main goal of fracture treatment is to return the patient to his usual activities as soon and as nearly normal as possible. The basic principles of fracture treatment were succinctly epitomized by the late Clay Ray Murray in an aphorism: "*Hypothetically, the ideal treatment for any fracture would be to wish the fragments into place, hold them there by moral suasion, and send the patient about his business while the fracture heals.*" Comprehension of the implications of this hypothesis is mandatory for good fracture treatment. Translated into practical terms, "to wish the fragments into place" means reduction with a minimum of additional tissue damage; "to hold them there by moral suasion" means maintenance of reduction with minimum limitation of normal function of the injured extremity; "to send the patient about his business while the fracture heals" means a method of treatment which least interferes with the usual activities of the patient. These established principles have remained unchanged for many years. The methods by which they may be applied are numerous and ever changing. The best method remains that which most nearly approaches the hypothetical ideal.

Open reduction and internal fixation is based upon these principles. The nearest approach to wishing the fragments into place is a technically adequate operative exposure, followed by gentle reduction under direct vision. The nearest approach to holding by moral suasion is rigid internal fixation. The maximum continuance of patient function is possible when he is encumbered to a minimum, or not at all, by external immobilization. Though operative treatment may approach the ideal, other less exacting and safer methods are available for management of most fractures. Only occasionally is operation the only means by which reduction can be obtained and maintained adequately. The specialized surgical judgment and ability needed, the surgical

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facilities necessary, and the constant associated hazards place stringent limitations upon the use of this method for the average fracture.

Safe and satisfactory operative treatment of fractures requires:

MINIMUM PREREQUISITES

Of the surgeon:

1. Judgment to select with certainty the cases requiring operation.
2. Adaptability, so that he may fit his plan of action to unexpected mechanical problems
3. Technical ability and a mechanical bent. It is a fact that except for the surgical technic required, any good carpenter would do a better job of internal fixation than most surgeons

And of the surgical environment:

1. A complete armamentarium of specialized tools for holding and stabilizing fracture fragments.
2. Adequate surgical and nursing assistance at operation
3. Inviolable operating room aseptic technic, from the operating surgeon to the junior nurse who may have the task of sterilizing the laundry and sponges
4. Adequate facilities for the postoperative hospital care of the patient.
5. Assurance of continuous supervision of the case throughout convalescence by the operating surgeon.

Surgical ability on the part of the operator is but one of the factors essential to success. Unless all the prerequisites are satisfied, open reduction and internal fixation cannot be justified except by urgent and absolute necessity.

TIMING OF OPERATION

The best time for open reduction and internal fixation is as soon as possible. The difficulties of reduction increase and the efficiency of fixation decreases progressively in direct proportion to the duration of the fracture. Except for those due to faulty technic, almost all complications and poor results occur in cases operated upon late or after other methods have failed repeatedly.

Common and Often Untenable Excuses for Delay.—1. Delay to let the swelling subside. Some delay may be warranted for treatment of established swelling around a fracture of more than thirty-six hours' duration. During the first twenty-four hours such a delay usually results in an increase rather than a decrease in swelling.

2. Delay to treat shock. Severe shock, especially with multiple injuries, warrants some delay for supportive therapy. The maximum benefits usually are realized within a few hours. When shock is the product of the fracture alone supportive therapy may logically be administered in concert with treatment of the fracture.

3. Delay for multiple skin preparations. The skin and underlying tis-

sues are in the best condition for operation at the moment of injury. Their condition deteriorates and the risk of infection increases progressively with the duration of the pathology. It is safer to operate through once-prepared healthy skin than through a thrice-prepared, tense and edematous area.

4. Delay for repeated attempts with conservative therapy. Each failure to secure reduction by a nonoperative method makes subsequent attempts less likely to succeed. Each additional attempt adds to the existing tissue damage and mitigates against a good result regardless of the method eventually utilized. It is fallacious and harmful to turn to open reduction as a last resort after running the gamut of conservative therapy unsuccessfully. If nonoperative measures are predestined to failure this can and should be determined at once, either by recognition of some innate characteristic of the lesion which requires surgery, or by the failure of one adequate trial of a closed method. Operation should then be carried out forthwith.

INDICATIONS FOR OPERATION

Absolute Necessity.—This indication exists only when reduction cannot be obtained or maintained by nonoperative measures.

In *fractures of the shaft of the tibia* operative reduction and fixation is required with:

1. Gross interposition of soft tissue between the fragments (always).
2. Transfixion of calf fascia by a bone spike (usually).
3. Multiple fractures at different levels (occasionally).

In *ankle fractures* operative reduction and fixation is required with:

1. A displaced posterior lip fragment involving one-third or more of the tibial weight-bearing surface (frequently). Small unreduced posterior lip fragments leave the ankle functionally unimpaired and may be ignored so long as the talus is accurately reduced.
2. Large displaced anterior lip fracture (always).
3. Impacted fracture of the lateral lip of the tibia, with displacement of 2 mm. or more (usually).
4. Fixed posterior dislocation of one fragment of a lateral malleolus fracture (always)

Relative Necessity.—This indication exists when nonoperative methods offer prospects of an uncertain end result and prolonged disability which may be avoided by operative therapy, and also when certain associated soft part injuries require operative intervention.

In *fractures of the shaft of the tibia* operative fixation may become a matter of relative necessity in the presence of:

1. A large intermediate bone fragment. Unless such a fragment is reduced and held in close approximation to each main fragment the risk of nonunion is great.
2. Damaged posterior tibial artery or tibial nerve. The operative management of nerve or vessel pathology is aided by preliminary reduction and fixation of contiguous fractures.

3 Multiple injuries in the same extremity. Over-all management of the injured limb may be facilitated by internal fixation of the fractured tibia.

In *fractures of the ankle* operation may become a matter of relative necessity in the presence of:

1. A tear of the inferior tibiofibular ligament, with diastasis of the ankle mortise
2. Malleolar fractures with lateral and medial subluxation of the talus.
3. Combinations of 1 and 2
4. Complete rupture of the deltoid ligament.

Open Fractures.—When debridement and cleansing of the fracture area is done coincident reduction under direct vision is indicated. Internal fixation should be applied if maintenance of reduction cannot be accomplished satisfactorily by external immobilization. In general this occurs in tibial shaft fractures characterized by a long intermediate fragment, and in ankle fractures with large displaced lip fragments or diastasis of the mortise. Internal fixation may be most advantageous when there is a surface defect which requires coverage by subsequent plastic procedures.

As a Method of Choice.—No fracture should be treated by open reduction and internal fixation when other methods are available unless all the circumstances are ideal and some real advantage can be assured by use of the operative method. This stipulation means that (1) all minimum requirements, as previously outlined, must be satisfied fully; (2) the fracture must be amenable to fixation rigid enough to make unnecessary or minimize postoperative external immobilization; (3) the patient must be intelligent and cooperative; (4) operative treatment must promise a faster and better result than any other form of treatment.

OPERATIVE TECHNIC

Preparation of the Skin.—The main objective of skin preparation is to obtain maximum surgical cleanliness with minimum additional tissue damage.

Preparation of a fractured tibia requires three persons. One applies steady traction to the forefoot. The second applies countertraction to

skin with the other. The cleansed area should extend from the toes to above the knee.

Two assistants hold the leg at the knee with one hand and cleanses with the other. The entire leg should be prepared.

Scrubbing should be gently done with soft material. Strong antiseptics are less effective than soap and water. The efficiency of the scrub

varies with its duration, the number of strokes and the number of rinses. The following technic has proved dependable:

1. Anaesthesia is established prior to removal of splints.
2. Manual traction and countertraction are applied immediately upon removal of splints.
3. The area to be cleansed is shaved.
4. A ten minute scrub (longer if necessary) with green soap and water is done, using sterile soft sea sponges, frequent gentle strokes and frequent rinses.
5. A two minute scrub with alcohol is done to remove residual soap and water from the skin.
6. A two minute scrub with ether removes alcohol and any residual greasy substance, leaving the skin dry.

The soap and water scrub is done by hand. Ether and alcohol are applied on sterile surgical sponges held by sterile long-handled forceps. During this part of the preparation the supporting hand at the fracture site should be covered by a sterile towel.

The extremity must be draped to allow free mobility and adequate exposure without risk of contamination. Two pairs of gloves should be worn by surgeons and nurses until the incision has been made and completely excluded from the surrounding skin. The outer gloves, along with the instruments used for the skin incision, are then discarded.

Skin Incisions.—Adequate exposure for fracture treatment requires a generous skin incision. A small incision usually proves to be false economy.

A good general utility incision for exposure of the tibial shaft (Fig. 551, A) extends from the region of the tubercle almost to the ankle with a gentle curve, convex lateral, avoiding the tibial crest except at either end. This approach has several advantages:

1. It provides an intact skin flap to cover the fracture site.
2. It lies over well vascularized soft tissue.
3. It provides access to both medial and lateral tibial surfaces.
4. Exposure of bone necessitates retraction in only one direction—medialwards.
5. The cosmetic result is good.

The posterior and medial surfaces of the tibia can be exposed simultaneously through a similar incision just behind the posteromedial angle of the bone. Incision should not be made over the subcutaneous surface of the tibia if it can be avoided.

Three general incisions have proved useful for exposure of the ankle:

The medial incision (Fig. 552, A) begins just back of the posteromedial border of the tibia in the lower third of the leg, passes downward behind the malleolus, then curves forward. The bone is exposed subperiosteally and the posterior tendons and neurovascular bundle are retracted backwards.

The lateral incision (Fig. 553, A) begins over the fibular shaft in the lower third, curves gently forward to run just in front of the anterior

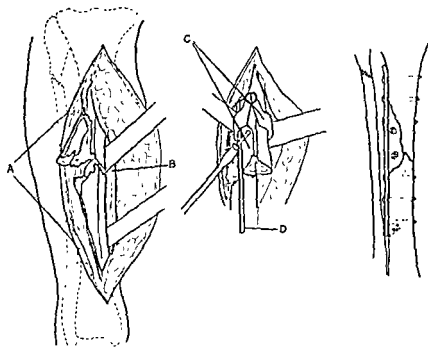


Fig. 551 —Exposure and fixation of tibial shaft fracture. *A*, Line of skin incision. *B*, Periosteum stripped from bone but left attached to overlying soft tissues. *C*, Loose intermediate fragment reduced, clamped and screwed to one of the two main fragments (whichever is easier). *D*, Free portion of plate to be clamped to other main fragment for freehand fixation.

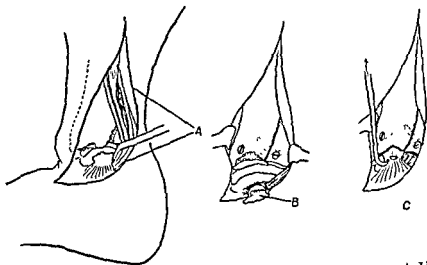


Fig. 552

screwed to parent bone.

edge of the bone, then curves backwards again below the tip of the malleolus. The peroneal tendons may be retracted backwards and the toe extensor tendons forwards to expose the tibiofibular syndesmosis or lateral tibial lip from in front.

The *anterior incision* is placed longitudinally over the ankle joint. The bone is approached medial or lateral to the anterior tibial tendon, depending upon the location of the lesion.

The Periosteum.—The periosteum usually is found to be stripped from both bone and soft tissue in the region of the fracture. Some additional periosteal elevation may be required for adequate exposure of the fracture. This may be done with impunity as long as the stripping is of periosteum from the bone (Fig. 551, *B*) rather than from the soft tissue through which it obtains its blood supply. Any periosteum separated from overlying soft parts is best excised and discarded since it will become a devitalized barrier to revascularization of the bone.

It is not necessary to repair lacerated or incised periosteum. Approximation of overlying attached soft tissues with a few interrupted sutures replaces the periosteum as effectively as an attempt to sew this delicate membrane.

The Reduction.—No recent fracture of the tibial shaft presents difficulty in reduction except when complicated by inadequate exposure or technic or actual loss of bone. The distal fragment is controlled by an assistant who exerts traction upon the foot while the surgeon gently replaces the fracture fragments in apposition. When a loose fragment is present some difficulty may be encountered if an attempt is made to reduce all the fragments simultaneously. The loose piece should be reduced and fastened to one main fragment (Fig. 551, *C*). This maneuver, by reducing the number of fragments to two, makes completion of the reduction a matter of relative ease. Associated fractures of the fibular shaft may be ignored. When the tibia is accurately reduced and fixed associated fibular fractures reduce spontaneously.

Fresh fractures of the malleoli are readily reduced if an assistant manipulates the foot to bring the talus into normal position while the surgeon replaces the malleolar fragment.

Disruption of the ankle mortise is corrected by reducing the talus, then pressing the fibula into its normal relationship with the tibia.

Accurate reduction of a large posterior lip fragment may present some difficulty. A generous exposure of the posterior and medial surfaces of the lower tibia is desirable. The fractured medial malleolus, which is almost always present with a lip fracture large enough to require operative replacement, is retracted distally (Fig. 552, *B*). The talus is reduced and the operator then gently fits the lip fragment in place. Reduction of the malleolus fracture follows fixation of the lip fragment.

Reduction of a fixed posterior dislocation of a fibular fragment is made difficult by the interosseous membrane, which may lock the fibula in its abnormal position. Liberal exposure is required. Reduction is accom-

(3) to be placed so that its center corresponds with the center of the fracture line.

(4) to contain at least six crew holes

The plate screws—

(1) to be centered exactly in each plate hole.

(2) to be inserted at an angle of exactly 90 degrees to the plate surface

(3) to be seated firmly in both cortices of the bone

(4) to have a shank diameter identical to that of the drill holes

Two Plane Fixation. One or more screws at right angles to the plane of the plate screws should be inserted to transfix both fragments (Figs 553, B and 555, A) Only by a second plane of fixation can adequate protection against rotational stress be provided

Omission of one or more of the preceding requirements is the usual cause for a mechanical failure of internal fixation Among the other common causes are:

1. An unsteady hand while drilling, which produces an oversized conical drill hole, or a broken drill bit
2. Wobbly or overenergetic insertion of a screw, which reams the threads from the drill hole
3. Failure to clamp the plate to the bone or one bone fragment to another continuously throughout the procedure of drilling the holes and inserting the screws, which leads to loss of correct relationship of plate to bone or fragment to fragment
4. Attempts to remove accidentally broken-off deep-seated portions of a drill or screw, which often result in further bone damage.

Unless easily extricated they are best left in situ

Internal fixation for fractures of the tibia usually is applied by one of two general techniques:

Clamped Reduction Technic—The plate is placed in the desired position on the bone surface with the fracture reduced Except when used to stabilize an open fracture, the plate should be on the lateral or posterior surface of the bone Multiple bone clamps are then applied to hold the plate firmly to the bone and also to hold the bone fragments in anatomical position All plate screws are inserted prior to removal of the clamps. If one clamp is in the way of a hole, another is applied nearby to take its place before it is removed. With the bone fragments clamped firmly together the transfixion screw is then inserted

Freehand Technic.—Occasionally it is difficult to hold the fragments reduced by clamps. When this occurs the position for the plate is determined It is clamped and screwed to one main fragment Reduction is then obtained and the free portion of the plate (Fig. 551, D) used to maintain the reduced position by clamping it to the other main fragment while the remaining screws are inserted

A loose or intermediate bone fragment is reduced, clamped and screwed to one of the main fragments (Fig. 551, C) Reduction and fixation of the two residual fragments is then completed. Additional transfixion

screws from the intermediate to the second main fragment should be inserted.

Internal fixation of fractures at the ankle joint requires attention to the same principles of technic which pertain to shaft fractures. Most ankle injuries in which operation is indicated involve several lesions. In general, if one component of an ankle fracture is to be treated by operative reduction and fixation, all should be treated in this manner.

The Medial Malleolus.—An assistant maintains reduction by engaging a bone hook into the malleolus fragment (Fig. 552, C). One or two screws are placed to run obliquely from the tip of the malleolus across the fracture line into the tibial metaphysis.

The Lateral Malleolus.—Reduction is maintained by a bone clamp. Two methods of fixation are available: (1) a long intramedullary screw is passed upwards from the tip of the malleolus across the fracture line and well into the fibular shaft (Fig. 553, C) or (2) a plate is screwed to the lateral surface of the bone. The first method is simple and adequate except when there is considerable comminution at the fracture line.

The Posterior Lip.—The lip fragment is held in position by a bone hook or clamp. Fixation is obtained by one or two screws which engage the cortex of the fragment and of the parent tibia (Fig. 552). It is often easier to place these screws from before backward than vice versa.

Ruptured Inferior Tibiofibular Ligament.—Two plates or washers and a long bolt (Fig. 554) provide secure approximation of the disrupted syndesmosis through the bolt. A hole is drilled transversely through the fibula, tibiofibular joint and tibia. Tenting of the skin over the drill point medially serves as a guide for placement of the medial incision. Plates and bolt are then applied and reduction secured by tightening the bolt. Either plate may at times be utilized for fixation of associated malleolar fractures.

The Anterior Lip of Tibia.—Screws engaging the cortex of the fragment and of the parent tibia are used.

Impacted Lateral Lip Fracture.—A small block of bone cut from the adjacent tibia may be inserted into the defect at the fracture line which results when the distal fragment is reduced downward.

Fixed Posterior Dislocation of Fibular Fragment.—The inferior tibiofibular ligament is inspected and, if torn, bolt fixation should be applied and the malleolar fracture stabilized as illustrated in Figure 554.

POSTOPERATIVE MANAGEMENT

Supplemental external immobilization of the extremity should be applied in the presence of insecure or nonrigid internal fixation as determined at the close of operation.

Protection by molded plaster splints is warranted even though internal fixation is rigid. Besides guarding against forces beyond the control of patient and surgeon, protective splinting provides comfort and assurance to the patient in the early postoperative period. After a few days

it may be removed without discomfort for gentle guided active exercises to maintain joint motion and muscle activity.

Elevation of the affected part above the level of the chest effectively minimizes swelling. Balanced suspension of the extremity until the wound is healed should be employed.

Sympathetic Nerve Block.—Undue swelling and pain despite adequate elevation is often strikingly relieved by procaine hydrochloride lumbar sympathetic block. This may be repeated if necessary.

Motion of Adjacent Joints.—The patient should actively move all joints which are not of necessity kept at rest. It is the surgeon's responsibility to see that this is done.

Care after Wound Healing.—If internal fixation is secure, the patient may be ambulatory with crutches as soon as the operative wound heals. He should continue active non-weight-bearing exercises, with protective splint for use at night and when travelling about.

Within three to eight weeks, depending on the character of the fracture and the fixation, weight bearing protected by a brace or walking boot is both possible and safe in most internally fixed fractures of the tibial shaft. Transverse fractures allow protected walking sooner than oblique or comminuted lesions. Boot or brace protection should continue until the fracture is healed.

Patients with ankle injuries, which include a lesion of the tibial weight-bearing surface (large lip fractures), are best kept from walking on the affected limb, even with boot protection, for at least six weeks. Depending on the patient's activities and the efficiency of the fixation, many patients with other ankle injuries may ambulate in a walking boot or short leg brace soon after operative wounds have healed.

Insecure internal fixation of a fractured tibial shaft calls for a circular plaster encasement extending from the toes to the groin with the knee flexed 25 degrees. Inadequate fixation of an ankle fracture requires appropriate external immobilization by boot or long-leg plaster. Under these circumstances the program must ignore the gesture of internal fixation and parallel that of closed reduction and external immobilization until consolidation of the fracture takes place.

SUMMARY

This discussion has touched upon certain salient points concerning open reduction and internal fixation of fractures. An attempt has been made to emphasize that this procedure is neither simple nor to be undertaken lightly. Under ordinary circumstances it is justified only by necessity. When this is the case it should be done as soon as possible. In order to carry out the procedure with safety and success specialized surgical judgment, skill and facilities are necessary. The hazards are serious and inescapable and the limitations of the method are numerous. But, when the prerequisites are satisfied and the operative method is properly carried out in the proper cases, many excellent results can be obtained that would be impossible by any other method.

NEW TRENDS IN PEDIATRIC SURGERY

Pectus Excavatum, Esophageal Atresia, Intussusception, Hirschsprung's Disease

MARK M. RAVITCH, M.D., F.A.C.S.*

PECTUS EXCAVATUM

Pectus excavatum is a congenital, frequently familial, deformity of the sternum, present at birth and usually progressive. It is marked by a sharp posterior curve of the body of the sternum, deepest just above its junction with the xiphoid. The lower costal cartilages bend inward to form a depression, the lateral borders of which are inclined more sharply than the superior and inferior portions. A paradoxical inward motion of the lower sternum is conspicuous on inspiration. In extreme instances the deepest portion of the concavity to one side of the midline may be posterior to the ventral surface of the vertebral bodies.

In infancy or early childhood, the deformity usually causes no physiological disturbance, although arrhythmias, particularly paroxysmal tachycardia, may occur. However, the progression of the deformity results in the chest becoming flat and thin, the dorsal spine kyphotic, the head thrust forward. In the undressed patient, the concavity is conspicuous and unsightly and a source of embarrassment. In the more severe instances, the deformity of the rib cage and spine is quite plain even when the patient is clothed. Displacement of the heart and pressure upon it may cause physiological changes, usually in adolescence or later. The occurrence of dyspnea and cardiac arrhythmia is not necessarily confined to the patients with the most severe deformities. In the adult, with a shallow, rigid chest, dyspnea may be on a pulmonary as well as a cardiac basis. The mechanism of the production of the defect is uncertain. A shortened central tendon of the diaphragm has been impugned by some. This might easily as well be merely a contracture secondary to the posterior displacement of the sternum and the deformity itself be due to abnormal growth of ribs and costal cartilages.

Operation should be undertaken in the more severe instances to correct the existing deformity and to prevent its progression.

Operation is indicated (1) to correct a deformity which is frequently a source of concern and embarrassment to children and parents, and a basis for teasing by playmates; (2) to prevent, or to correct the antero-posterior flattening of the chest and the dorsal kyphosis; (3) to relieve dyspnea, exercise intolerance, or cardiac arrhythmias, or to prevent their appearance.

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It is not possible to say in which child or infant the deformity will progress most and cause most severe symptoms if operation is withheld. A less formidable operation in infancy may well lead to a more or less normal thoracic condition while a more extensive operation some years later may secure only partial correction of the deformity.

Although irregularly successful results have been intermittently reported for some fifty years, the modern operative treatment for pectus excavatum has been developed in the last ten years. Ochsner and De Bakey, Lincoln Brown, Sweet, and Lester have reported successful results with fundamentally similar procedures.

The procedure we have employed differs from these in some respects. It aims at preventing further deformity and at correcting the existing deformity.

Technic.—Under intratracheal ether anesthesia, a midline incision is made from the manubrium to the epigastrium. The pectoral muscles are stripped back on either side to lay bare all the involved costal cartilages. Because the xiphoid is pulled sharply inward and the lower costal cartilages on either side are squeezed together like the ribs of a fan, the xiphoid is relatively inaccessible until these costal cartilages have been removed. The two lowermost costal cartilages on either side are removed, together with their perichondria. In infants and small children, the perichondrium is so delicate as almost to defy preservation and we have found it best to remove it with the costal cartilages. The xiphoid is now separated from the sternum and the substernal ligament is divided. At times, the ligament parts audibly and the sternum gives visibly when the band has been released. This much of the procedure, the so-called limited operation, apparently would arrest the progression of the deformity but does not correct the existing deformity and we have not been satisfied to stop with the limited procedure. On either side the deformed costal cartilages are now removed for the entire distance of their incurvation so that no abnormally curved cartilage remains. We have removed from three to five cartilages on either side. The intercostal bundles are completely divided on both sides so that the hand can be passed behind and on both sides of the sternum, which is attached only to the manubrium.

A transverse wedge osteotomy is now performed at the superior border of the defect. An ordinary gouge is the simplest and most satisfactory instrument for this purpose. The sternum is now tilted sharply anteriorly until the posterior cortical lamella has been fractured, permitting the sternum to remain in the corrected position in permanent position. The sternum is now sutured in position through the bone across the defect.

The rectus abdominis muscle is merely introduced into the defect from the traction wire. The pectoral muscles are not sutured to the sternum superiorly. The rectus muscles are not reattached. In most cases, the sternum which had been pressing

against the heart or actually displacing it is found at this point in the operation to be separated from the anterior surface of the heart by a distance of several centimeters. The pleura may be entered on one side or the other, but if this is recognized and the pleura aspirated at the conclusion of the operation, no harm results.

The children seem to tolerate the operation remarkably well. Several of them have shown moderate tachycardia for two or three days, and those who have had a perforation of the pleura with the leakage of a

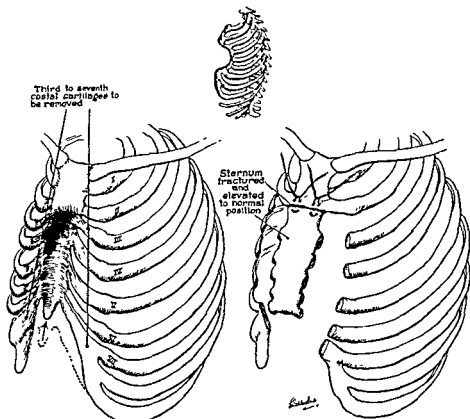


Fig 556 —The drawings show the nature of the defect in a case of pectus excavatum with moderately severe deformity. The deformed costal cartilages are removed for the full extent and the sternum freed by a transverse wedge osteotomy to be fractured anteriorly.

little blood into the pleural cavity have had fever for two or three days. Most of the children have been out of bed within a day or two after the operation. Despite the large defect and the absence of any protective device, the children have not suffered from any respiratory distress or paradoxical motion of the chest wall. Within three weeks the fracture has healed and a nearly solid chest wall results (Fig. 557).

The most gratifying result is the difference in appearance of the patient on deep inspiration. Instead of a protuberant abdomen and depressed sternum on inspiration, the child demonstrates a flat "sucked-in"

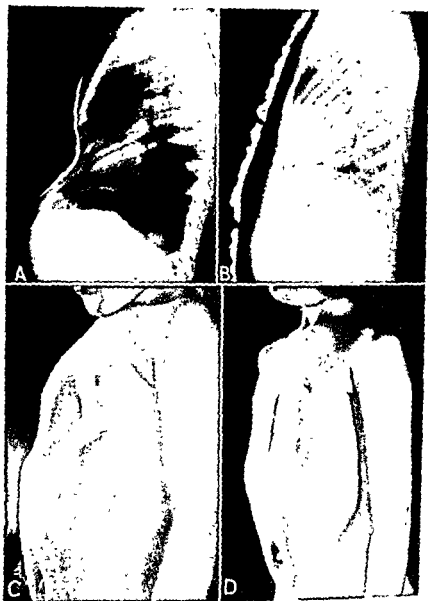


Fig. 557 —A, B,—Preoperative and postoperative roentgenograms of a 5 year old girl with a moderate funnel chest deformity. Barium paste applied to the skin in the midline aids in visualization of the sternum.

C, D, Preoperative and postoperative photographs of same patient taken in deep inspiration. Note that after operation the chest fills out and the abdomen is drawn in.

abdomen, and full rounded chest. Since the sternum has been freed of its costal and diaphragmatic attachments, there is no mechanism by which the defect or the deformity can be recreated and the postoperative results have been extremely satisfactory as the patients have been followed.

ESOPHAGEAL ATRESIA AND TRACHEO-ESOPHAGEAL FISTULA

The appearance in 1913 of the report by Cameron Haight put the treatment of esophageal atresia and tracheo-esophageal fistula on a rational basis and gave tremendous impetus to the operative attack on the lesion. Until that time, a few babies had been preserved by the complicated method of ligation of the tracheo-esophageal fistula, closure of the lower esophageal end, gastrostomy, and exteriorization of the proximal esophagus as a cervical esophageal fistula. A very few of these babies subsequently went on to antethoracic esophagoplasty performed by the tedious multiple staged procedures then in vogue. As the result of the stimulus of Dr. Haight's publication, a large number of babies, perhaps two or three hundred, have now been operated upon by this method the country over.

The deformity consists of complete atresia of the upper esophagus, generally at the level of the third or fourth thoracic vertebra. The esophagus ends blindly and the proximal segment is tremendously dilated and hypertrophied as a result of futile attempts at swallowing in the final period of gestation. The distal esophagus in most cases communicates with the trachea at the carina or a little above in a tracheo-esophageal fistula.

The symptoms of complete esophageal obstruction are frothing and bubbling of saliva from the mouth and regurgitation of any ingested material, beginning at birth, with accompanying attacks of cyanosis. The diagnosis of esophageal atresia must be suspected in all newborn infants with such symptoms. Pneumonia from aspiration of saliva and feedings is almost inevitable within a few days after birth. The diagnosis is most easily established by the passage of a radiopaque rubber catheter into the esophagus under the fluoroscope. The catheter usually will be found to stop at the level of the third or fourth thoracic vertebra. A small amount of iodized oil (not barium) may be injected for roentgenography and then aspirated with the catheter. The proximal esophageal pouch will be found to be considerably dilated (Fig. 558). If in addition the roentgenograms show air in the intestinal tract, a communication must exist between the lower esophageal segment and the trachea. More rarely still, there is no fistula at all. Figure 559 shows the situation which exists in more than 95 per cent of cases.

Although occasionally infants survive as long as a month before operation, the condition uncorrected is incompatible with life. For correction, the esophageal obstruction must be relieved and the tracheo-esophageal communication closed. The direct operative attack on the lesion has given the greatest success.

In preparation for operation, the infant must be hydrated, any pneumonia present must be combated and further aspiration prevented. Constant suction is made through a small catheter passed by nose or mouth into the proximal esophagus. This is the single most important item in the care of these infants before and after operation. The crib is tilted so that the head is elevated, allowing continuous removal of the

only, not penetrating the mucosa. However, it is probable that most of the sutures of both rows in the thin distal segment will be through and through. A little added protection for the suture line is secured if the distal end can be telescoped into the proximal end. A soft strip of rubber tissue is brought out through the chest wound at the time of closure. Postoperative care continues the preoperative regimen. The catheter is left in the pharynx or proximal esophageal segment for constant suction but is not passed through the anastomosis. If it is seen after a day or



Fig. 560.—Postoperative barium swallow ten days after operation for esophageal atresia and tracheo-esophageal fistula. This infant did not require a gastrostomy.

two that very little saliva is aspirated through the catheter, glucose may be given by mouth, and feeding begun thereafter as indicated in the

hydrolyzate. Lucilia at the suture line may be a problem for a week or more, and total intravenous alimentation is a difficult problem in infants. It is, therefore, frequently advisable to perform a gastrostomy on the third to the fifth day after operation. Occasionally, infants are able to swallow soon enough to escape gastrostomy (Fig. 560).

If a gastrostomy is to be performed, it should be to the right of the midline so as to leave the left upper quadrant free of scars in the event that antethoracic esophagoplasty becomes necessary.

Fistula and stricture are the most common postoperative complications. A salivary fistula through the operative wound is fairly common and almost invariably of brief duration, and of no consequence. Stricture formation is more serious and should be watched for both with lipiodol roentgenography and by observation of the infant during feeding time. Occasionally, strictures may develop after several weeks in infants who have been doing well up to that time. If a stricture is developing, the infant should be made to swallow a silk thread which may then be fished out of the stomach by a suction tube or a plastic crochet needle inserted through the gastrostomy. Dilatation may then be accomplished by the passage of Salzer bougies—rubber catheters filled with fine lead shot. The silk thread makes it feasible, if necessary, to pull plastic beads or threaded sounds through the stricture. Stricture formation has not proved to be a formidable complication.

In a small group of cases, direct anastomosis will prove to be impossible because of the distance between segments or because of the absence of the distal segment. The latter condition may be suspected if there is no gas in the intestines in the preoperative roentgenogram. In addition, in a certain number of infants in whom the anastomosis is attempted, dense stricture formation will result with severe stenosis which defies attempts at reconstruction. In infants of both of these groups, an antethoracic esophagoplasty (Fig. 561) is the procedure of choice. Although it has been demonstrated by Sweet and by Swenson that it is possible to bring the stomach high in the chest of such babies to perform an anastomosis with the cervical esophagus, an antethoracic esophagoplasty is a much safer procedure. The proximal esophageal segment is exteriorized in the neck. The tracheo-esophageal fistula is closed. The esophagus and intestinal tracts are then connected by tubes of skin or of intestine, or both. Such reconstructions, once completed, are entirely satisfactory. As can be seen from the illustration (Fig. 561, *B*), it is possible to bring the jejunum up into the neck in one stage, and to perform an anastomosis in the second stage. This is a quick and relatively safe operative procedure and probably involves less physiologic disturbance than bringing the stomach through the chest. If the jejunum does not quite reach to the neck or if it is preferred not to mobilize much jejunum, it is possible (Fig. 561, *A*) to construct the upper esophagus of skin and the lower of jejunum in a two or three stage procedure. Several authors have reported successful construction of an esophagus made entirely of skin, but in general this method is fraught with difficulty.

INTUSSUSCEPTION

Intussusception has always been one of the most interesting and most serious conditions with which the pediatric surgeon has to deal. Since Jonathan Hutchinson, in 1871, performed the first successful operation

for intussusception in a child, a baby of two years, there has been a steady, although painfully slow, improvement in mortality from this disease. The striking fact is that only in very recent years have even the larger clinics approached or improved upon the mortality reported over fifty years ago by Hirschsprung in Copenhagen, and not long after that by Clubbe and then by Hipsley in Australia with nonoperative methods of reduction. Recently, there has been a recrudescence of in-

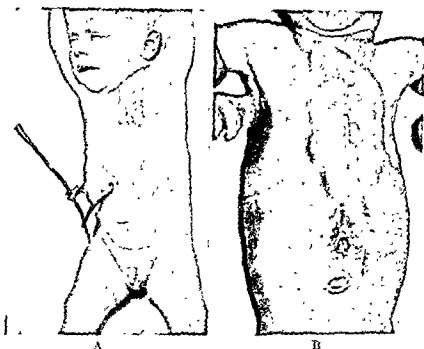


Fig 561 —A, Antethoracic esophagus constructed by the author after failure of primary anastomosis. The upper portion is lined by skin of the chest wall and covered by a split thickness graft. The lower segment is composed of a loop of extrapolated jejunum anastomosed to the stomach. The gastrostomy tube has not yet been removed.

B, Antethoracic esophagus constructed by Dr. W. P. Longmire in an infant who had no distal esophageal segment. A loop of jejunum has been brought up into the neck and anastomosed to the esophagus. The gastrostomy has already been permitted to close.

terest in the nonoperative reduction of intussusception with the use of hydrostatic pressure.

The clinical features of intussusception are well established. Chiefly affected are infants in the first two years of life. Males are affected more frequently than females in the ratio of 3:2. In less than 10 per cent of the reported cases a polyp, diverticulum, nodule of ectopic pancreatic tissue, or other local lesion is found to act as the exciting cause. In the large majority of cases, the intussusception begins at or near the ileocecal valve. Once an intussusception forms, the leading point is constant. Increase in length of the intussusception occurs at the expense of the

sheathing or receiving loop—the intussusciens. Compression of the mesenteric vessels between the two inner layers and the U-shaped angulation of the mesenteric vessels at either end of the intussusceptum lead to venous stasis, engorgement, edema, exudation, further vascular compression, and ultimately gangrene. Discharge of blood into the bowel is one of the first results, and the early discharge of quantities of mucous is correlated with the appearance of great numbers of goblet cells in the mucosa of the intussusceptum. The tension of the mesentery on the intussusceptum tends to arch the intussuscepted mass in a curve. Edema and compression produce intestinal obstruction, although most patients should be relieved of their intussusception before they have come to suffer from ileus. The rapidity of appearance of gangrene is highly variable, and, in some instances, gangrene is probably attributable to the trauma of operative manipulation. At times, the bowel is viable and reducible after a week whereas, at other times, an intussusception may become irreducible within twenty-four hours.

The attack is usually heralded by vomiting and a sudden cry due to abdominal colic. The attacks of colic recur regularly. In the intervals, the infant tends to be listless and apathetic. Usually one normal stool is evacuated, emptying the colon. Thereafter, only blood or blood and mucus are passed. The abdomen is relaxed, soft, and is nontender, except at times over a palpable intussusceptum. Signs of ileus gradually supervene—distention, vomiting and tachycardia. Fever and leukocytosis are common by the time the children present themselves at the hospital, and high fever is of grave prognostic significance. Blood in rectal discharge was seen in 91 per cent of our 152 cases. Inasmuch as an occasional child continues to have small stools or bloody diarrhea in the presence of intussusception, caution must be exercised in making the diagnosis of dysentery solely on the basis of bloody stools. The intussusceptum is frequently palpable by rectum and it is noteworthy that occasionally a mass is palpable by rectum which is not palpable abdominally.

Treatment.—The barium enema reduction technic which we employ is as follows: As soon as the presumptive diagnosis of intussusception is made, the operating room is told to stand by for a laparotomy. The child is taken to the fluoroscopic room in the dispensary, an ungreased Foley bag catheter is inserted in the rectum, and the bag distended with air. Barium is permitted to run in from a height of three feet while an assistant squeezes the buttocks tightly together throughout the procedure. The barium usually runs rapidly through the bowel until it meets the intussusception, which arrests the barium column, giving its leading edge a concave meniscus (Fig. 562). The meniscus flattens out and then begins to deepen again, and so on. The ends of the meniscus gradually extend proximally until suddenly the intussusceptum gives ground. At times, an intussusception may be reduced from the rectum or sigmoid through the ileocecal valve almost too quickly for one to observe the process. At other times, there is a stubborn hang at one

point or another. If the intussusception appears not to reduce itself beyond such a point, the child is permitted to expel the barium and a second, and if necessary, a third enema is administered. The chief difficulty may be in deciding upon the completeness of reduction of the intussusception at the cecum. By displacing the cecum laterally, one may see barium well up in the small bowel. After reduction, the child is

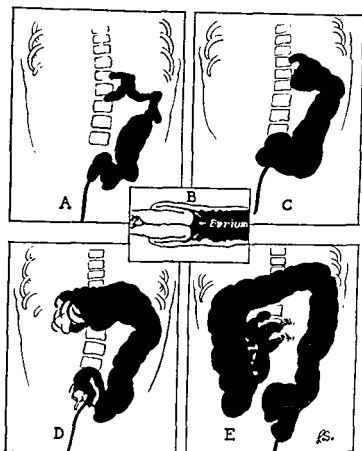


Fig 562 — Drawings of the fluoroscopic appearance during barium enema reduction of an intussusception. Note, as reduction proceeds, how the horns of the meniscus extend until suddenly the intussusception advances rapidly, the meniscus flattens out and reforms. Barium should be seen well into the small bowel when reduction is complete.

sent to the ward, powdered charcoal is instilled in the stomach and six hours later an enema given to recover the charcoal. Successful reduction is denoted by the following criteria: (1) the entrance of barium well into the small bowel, (2) return of the barium with feces or with flatus, (3) disappearance of the mass, (4) clinical improvement of the child who often falls into a natural sleep, and (5) subsequent recovery in the stool of charcoal given by mouth or the appearance of a blood-free stool.

Since 1939, we have treated thirty-six patients by this method, with no deaths. In nine patients, the intussusception was reduced only as far as the cecum but not through the ileocecal valve, and it was necessary at operation, usually through a McBurney incision, to complete the last inch or so of the reduction manually.

The recent experience of the larger clinics indicates that, as far as mortality is concerned, the figures are reaching an irreducible minimum. In the hospitals with the greatest experience, most of the deaths which occur are in children moribund on admission. Even when this happy state has been achieved, however, there will still be found a much lower morbidity and much shorter hospital stay in the patients treated by hydrostatic pressure than in those treated by primary operative reduction. The comparative figures at Johns Hopkins Hospital for duration of hospital stay are an average of 9.2 days for children treated primarily by enema, and 32.4 days for children treated primarily by operation.

There is adequate clinical and experimental evidence to show that with a hydrostatic pressure of 3 to 3½ feet, it is not possible to reduce gangrenous bowel. Furthermore, the brunt of the resistance to pressure is borne by the healthy viable bowel of the intussusciptens, so that rupture is not likely to occur. In fact, rupture has only rarely been reported to result, and this has usually been in connection with the addition of manipulation of the intussusception through the abdominal wall. We employ the barium enema method in all cases of intussusception regardless of the duration of the disease or the gravity of the illness in the patient. It is possible to perform the reduction while intravenous fluids or blood are being administered. If there is any uncertainty about the completeness of reduction, a McBurney incision should be made.

It is emphasized that hydrostatic pressure reduction is a surgical procedure which should be carried out by surgeons and in a hospital with everything in readiness for operation.

HIRSCHSPRUNG'S DISEASE

The diagnosis of Hirschsprung's disease is rather difficult to establish with categorical certainty because there is no pathological lesion which is accepted as pathognomonic, although recent publications (Bodian et al.) continue to suggest that it may be possible to demonstrate some lesion in the myenteric plexuses in cases of Hirschsprung's disease. The diagnosis of Hirschsprung's disease is usually made on the basis of stubborn constipation in a child in whom a barium enema shows a tremendously dilated colon, usually with poor haustral markings. Because the diagnosis is made on such scanty evidence, bizarre misdiagnoses are at times made. We have seen cases diagnosed as Hirschsprung's disease in which the cause of the intestinal dilatation was discovered to be actually one of such several diverse lesions as anal stricture due to poor repair of an imperforate anus, cretinism, in which the constipation and the dilatation of the colon were corrected by the administration of thyroid extract, and behavior problems in children who "fought the pot" and

normal in some instances, but the redundant bowel remains a mechanical hazard. In one instance, sympathectomy produced daily spontaneous evacuation for a year in a child who had had no previous spontaneous stools. He remained distended with gas and suffered attacks of abdominal pain (Fig 563). A left-sided colectomy produced complete relief.

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RECENT DEVELOPMENTS IN PLASTIC SURGERY

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The more important recent developments in plastic surgery have arisen from a broader application of established fundamental principles. Because the scope of the field of general plastic surgery is so broad, I shall present only some of the problems involving wound closure, or what might be termed the reconstruction of certain surface defects. It is true that these are not new problems, but the success in their management has been improved greatly from a better understanding and knowledge of skin grafting procedures.

TYPES OF SKIN GRAFTS

A detailed discussion of skin grafting operations has been presented heretofore¹ but it is appropriate to review briefly some of the characteristics of the various types of grafts. The different kinds of skin grafts vary in functional and cosmetic results largely with their thickness and source. The free *full-thickness* or *Wolfe graft* will give one the optimum cosmetic and functional result because the entire layer of elastic fibers is included in it. However, it is the most difficult to apply and make grow, and hence has a limited field of usefulness. It is used primarily on the face where one wishes to secure the best cosmetic result or on the flexor surface of the hand or fingers where the maximum degree of elasticity and the greatest surface resistant qualities are needed.

For the closure of the greater majority of wounds necessitating a free skin graft, the *split* or *partial-thickness* variety gives the greatest diversity of practical usefulness. One that is cut to approximately 75 per cent total skin thickness offers most of the qualities that we find in the free full-thickness graft but its technical use is much simpler. In large open areas such as one encounters in extensive avulsions, surgical excisions or in granulating defects following third degree burns, a thinner split-thickness skin graft is used most commonly. These are ordinarily cut anywhere from one-quarter to one-third total skin thickness. Being thin, they vascularize rapidly and with a high degree of certainty. Their donor sites heal quickly and frequently are utilized repeatedly for the removal of successive "crops" of thin split-thickness skin grafts. This is an important item in covering an extensively burned patient, when donor sites are frequently insufficient in surface area to yield adequate skin covering.

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There are times when one must transfer subcutaneous fat with a skin graft. Such coverings can only be made when a pedicle is left attached to maintain viability until new vascularization is established in the recipient area. Flaps of this variety may be obtained by rotating them over the defect from the adjacent wound border, or by transference from a distant site either as a "direct" flap or as one that has been "tubed" prior to removal. Skin and subcutaneous covering is needed when one wishes to close over exposed tendons or joints, so as to insure subsequent kinetic activity. It is also needed to cover open bone or joint defects in which subsequent future orthopedic or peripheral nerve surgery may be anticipated. It may also be needed to reconstruct the normal subcutaneous padding or in areas of poor vascularity following excessive irradiation where a free graft might not survive.

And finally, in this brief résumé of the indications for and characteristics of the different types of skin grafts, one cannot refrain from including a statement regarding the practicability of transferring skin from one person to another. It is now a well established fact that *except in identical twins*, skin taken from anyone other than an autogenous donor will grow for only a very short time, i.e., three to six weeks. At the end of this period it becomes rapidly necrotic and must be removed. The practical value of this procedure is limited to the treatment of severe burns in the early stages of the disease.

only when on a poor-risk extensive burn, up to a point at which he may withstand the removal of skin grafts from his own body. It must therefore be looked upon as a temporary procedure which in rare instances may prove to be a life-saving measure.

Concluding this short discussion of skin grafts, I wish now to present a brief summary of the application of skin grafts to the treatment of burns.

SKIN LOSS FOLLOWING BURNS

Great strides have been made during recent years in the treatment of burns. Much more is known regarding the pathologic physiology of the burned patient and how to correct it. Marked improvement in the local treatment of burns has occurred. The pressure dressing methods of Koch and Allen² have received wide acceptance. The procedure, however, does have some disadvantage in dealing with burns of the hand, since the necessary immobilization tends to aggravate stiffness in the metacarpal and phalangeal joints. It would seem that insofar as the care of burned hands is concerned, the methods advocated and used by McIndoe³ in the British Royal Air Force may be of superior merit. He recommends constant elevation of the hands so as to minimize edema. Locally the burns are covered with light saline dressings and frequent finger motion is encouraged. This simple method does much to maintain better permanent joint function, but does entail extensive meticulous constant care.

Following the local treatment, there is a marked trend towards débrid-

ing all burned surfaces early, i.e., as soon as a line of demarcation is apparent. This is followed by immediate skin grafting. The early covering with a permanent skin graft will minimize late fibrosis of the joint structures and will give the best final functional result in the minimum length of time.

There have been a few isolated advocates of primary excision of the local burn, which is followed by the application of an immediate skin graft. While this would be an ideal procedure, most plastic surgeons (including the author¹) feel that until a better method is available of determining just how deep a fresh burn extends, the procedure is impractical. This point is stressed because if one underestimates the depth of the burn damage, subsequent inevitable underlying necrosis will result in loss of the skin graft above it. If one assumes a more radical viewpoint, then good tissues will be sacrificed needlessly. Hence, most of us feel that early débridement is desirable, but only when a line of demarcation has become established. This ordinarily occurs in seven to twelve days following the initial thermal injury. Removal of necrotic tissue at this time is of course ideal. If the underlying wound shows evidence of total skin thickness destruction, one should then proceed to cover the area with a properly selected type of skin graft as soon as the recipient area has been adequately prepared.

CHRONIC LOWER LEG ULCERS

Chronic leg ulcers originate from a variety of sources but more commonly follow as complications arising from the passive congestion associated with varicose veins, from thrombophlebitis, from deep third degree burns or from soft tissue trauma associated with compound fractures. One is frequently appalled by the prolonged disability experienced and the fantastic sums of money spent for "magic ointments" by this group of patients, who continue struggling with their ulcers until a different approach to the problem is undertaken.

Two important underlying factors must be considered before any chronic leg ulcer can be healed. It is well known that the basic blood supply to the soft tissue coverings of the lower leg is very poor in comparison with other areas of the body. If an ulcer occurs in the lower leg and can be encouraged to heal, it is apt to break down repeatedly because the scarring incidental to healing is poorly vascularized and will not withstand ordinary daily trauma. Secondly, the local blood supply is diminished further because of arteriosclerotic vascular disease, varicosities, thrombophlebitis or the dense scarring that frequently is associated with deep burns or compound fractures. Consequently, the ideal treatment of a lower leg ulcer is to cover it with a skin graft, since this type of surface restoration will be associated with a minimum degree of local scarring and hence better vascularization when healing is ultimately accomplished.

Before any type of skin grafting can be executed successfully in a lesion of this type, adequate preparation of the base must be carried out

first. This involves treatment of all underlying lesions. Varicose veins must be eliminated by accepted methods. Edema is removed by bed rest and with support and elevation of the extremity. Finally, the chronic ulcer along with all adjacent and underlying necrotic tissue and scarring must be excised widely. The level of excision must be carried back to what appears to be an adequate blood supply as noted by local bleeding and absence of further fibrosis. In the majority of cases, some of the underlying subcutaneous fat pad will remain present and such a defect may be covered out in conjunction with antibiotic graft may be applied at once er, where there



Fig. 564—A, Chronic ulcer of ankle following compound fracture. B, Completed reconstruction.

has been much fibrosis and extensive capillary oozing, one may anticipate the development of a complicating hematoma beneath the graft. In these cases, it is wiser to dress the defect with some type of wet dressing technic until an adequate smooth granulating bed has been obtained, i.e., in seven to twelve days, and then proceed to carry out the skin grafting procedure.

In a smaller group of chronic leg ulcers, the necessary excision may have to be carried so deeply that the underlying tendons and tibia may be left exposed. In addition, the local adjacent circulation may be extremely poor. In this variety of cases, it is desirable to cover the wound with skin plus subcutaneous fat. This must of course be done with a pedicle flap, either a direct flap (Figs. 564-568) or one which has been

previously tubed. It must be remembered, however, that the use of pedicle flaps in this more serious group of leg ulcers is idealistic but not always practical. The procedure can be executed well in the young and middle age group of patients with flexible joints. However, stiff joints

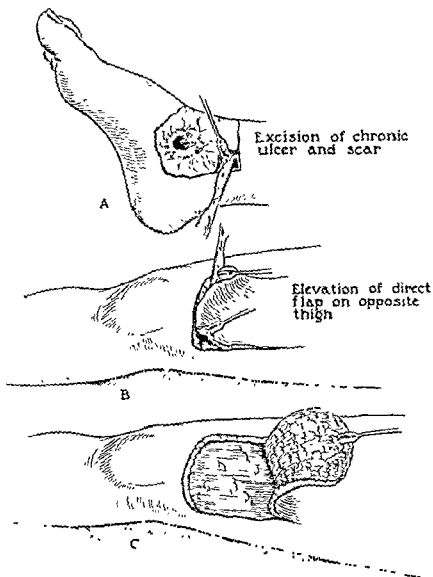


Fig. 565.—Technic of reconstruction. Excision of ulcer with adjacent scar and elevation of direct flap from opposite thigh. We feel that thigh flaps are far superior to lower leg flaps because their blood supply is better. The position incidental to transfer when thigh flaps are used seems no more awkward or uncomfortable to the patient than when the lower leg is chosen as the donor site.

and more advanced age may preclude the use of this more complicated operation in many instances. In such cases, one must compromise by utilizing a split-thickness graft even though it will not give the most desirable end result.

Finally, after healing has been accomplished with a well executed skin

grafting operation, it must be remembered that the new covering must be protected in the future from trauma and by external elastic support when indicated. Failure to observe this may result in breakdown of the graft and disappointment to both the patient and surgeon.

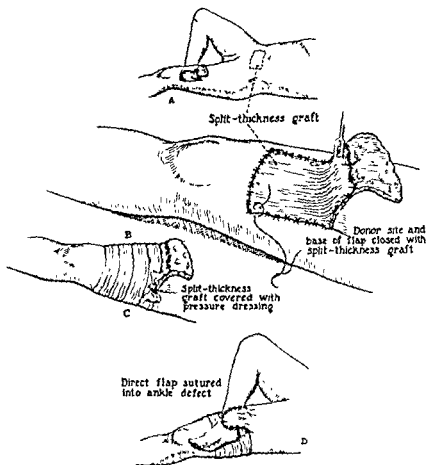


Fig 566.—Technic of reconstruction (continued) Thigh flap elevated The donor bed and open portion of the flap base are lined with a primary split-thickness skin graft so as to convert all open areas into a closed wound, thus minimizing infection. The free graft is covered with a pressure dressing following which the open portion of the flap is sutured into the defect of the opposite ankle as prepared in Figure 565

DECUBITUS ULCERS IN PARAPLEGICS

Until World War II, the management of the inevitable decubitus ulcers in paraplegics was poorly understood, and their treatment equally unsuccessful. Most patients died within a relatively short span because of inanition and complicating organic infections. But because of many advances in chemotherapy and recognition of hypoproteinemias, combined with the large group of paraplegics assembled in a few large

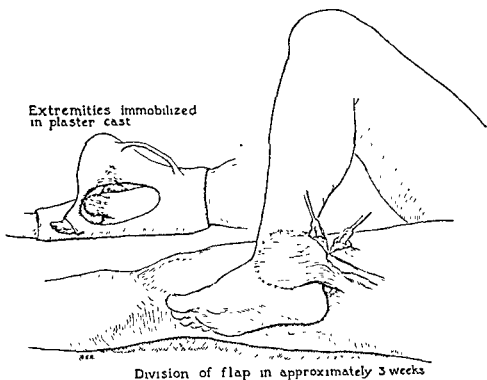


Fig. 567.—Technic of reconstruction (*continued*). The flap is sutured in place and the lower extremities secured together in plaster of paris. It is usually safe to divide the flap in approximately three weeks.

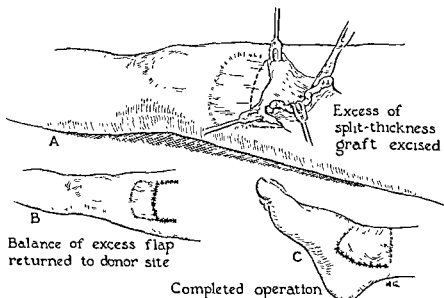


Fig. 568.—Technic of reconstruction (*concluded*). The transferred end of the flap is sutured into the ankle. The excess flap is returned to the donor site from which it was taken on the opposite thigh. Prior to suturing down, the excess temporary split-skin graft lining is excised, leaving only that portion on the distal end of the thigh that represents the surface covering transferred to the ankle.

Veterans Administration hospitals following injuries in World War II, an opportunity has arisen to study these cases in a way that has been unprecedented. Our study reported heretofore,^{4, 5} arises from the results of approximately 350 operations carried out on the Plastic Surgery Service at the U. S. Veterans Administration Hospital at Hines, Illinois during the past two years. Our observations parallel closely those reported by Conway⁶ and associates from the Plastic Surgery Service at the Veterans Administration Hospital, Bronx, New York.

Our interest in this problem was twofold. In the first place, the large number of patients so afflicted needed treatment. Secondly, many patients were admitted to our service who had had numerous previous unsuccessful operations based upon a variety of procedures, and unfortunately had been reported prematurely in the literature as cures, only to break down later.

General Care.—Our attention was first directed to the general condition of the patients. Those whom we saw were all debilitated, anemic and suffering from hypoproteinemia. The general nutrition of the patient must of course be corrected. He should be placed on a high protein, high caloric and high vitamin diet. Repeated transfusions of whole blood are given as indicated. Routine preoperative and postoperative penicillin therapy is given in large doses until the sutures have been removed. To this is added sulfasuxidine in 6 gm. doses three times a day for one week preceding all operations upon ischial ulcers, and continued until the postoperative wounds have healed.

Naturally, meticulous nursing care is imperative. The ulcers as such are found to occur over all bony prominences around the pelvic girdle, as over the sacrum, trochanters, ischial tuberosities and anterior superior iliac spines. One frequently finds a relatively small opening through the skin, but with careful probing it is usually observed that there is wide undermining of the soft tissues beneath the sinus.

Excision of Ulcer and Bony Prominences.—Because of the importance of the occurrence of bedsores over bony prominences, it was pointed out early by Blockma^{7, 8} that these should be removed along with wide excision of the ulcer itself. This maneuver eliminates potential future pressure points after closure of the ulcer. Although preoperative x-ray films are usually negative, microscopic study of the removed bony spines and tuberosities shows evidence of fibrositis and chronic osteomyelitis in a high percentage of cases, which in itself would preclude successful healing following any procedure. A third reason for removing the bony prominence is that the procedure opens into the medullary cavity of the underlying bone. This gives rise to an additional source of blood supply and hence furnishes more nourishment to the wound. This in turn naturally aids in healing.

Skin Grafting.—The cutaneous defect following surgical excision of the ulcer and underlying bony prominence must next be closed with skin and subcutaneous fat. The method of accomplishing this depends somewhat upon the location and size of the ulcer. Those over the sacrum

may often be closed by an S-plasty, providing there is enough available covering with which to carry out this procedure. Where one needs additional covering because of the magnitude of the defect to be closed, the best and most easily obtainable tissue is obtained by utilizing a direct rotation flap constructed from the border of the opening. The same procedure is used for closure of trochanteric openings. We feel it is imperative that these flaps be rotated and sutured into their new beds without any tension whatsoever, and in order to insure this, the donor site from which the rotation flap is procured is covered with a primary split-thickness skin graft. When the wound is finally closed, it is covered with a very copious dressing secured under moderate pressure. We have found bias-cut wide bandages of stockinette ideal for this purpose.

Management of Ischial Ulcers.—Following the development of the foregoing general plan of treatment of decubitus ulcers in paraplegics, the over-all results have been unusually successful. It is of interest to note that we now see very few sacral or trochanteric ulcers except in new patients assigned to the service. This is because the patients are now out of bed the greater portion of the time. But because of this fact, the incidence of ischial and recurrent ischial ulcers has increased because the patients spend more time in the sitting position. We have consequently had to become more radical in the management of the ulcers over the ischii and now are carrying out the following technic for these lesions.

After dissecting the ulcer with its cavity down to the ischial tuberosity, the bone is exposed (leaving the ulcer still attached to the tuberosity) and a Gigli saw passed through the obturator foramen. A complete removal of the tuberosity along with a segment of the horizontal and pubic rami is then carried out, removing the bone and attached ulcer in one unit. The rami are then trimmed further with a large rongeur, going back far enough to remove the bony fulcrum of the obturator internus muscle. Bleeding from the cut ends of the bone is controlled with buried sponges of Gelfoam. The obturator internus muscle is then spread out to be sutured over the lateral ramus, to the obturator externus muscle and to the cut origin of the biceps femoris muscle. Because of the extensive resection of the ischium it is possible to close practically every wound by primary suture since the divided skin and subcutaneous flaps fall into the cavity without tension. This type of closure for ischial ulcers is followed by rapid healing and a minimal number of postoperative complications. The patients who can walk with the aid of braces get around very well without any evidence of pelvic instability.

Finally, it must be remembered that these patients are and always will be anesthetic below the level of their respective spinal cord injuries. Because of this their nursing care must be continued and every possible effort made to avoid prolonged pressure on any one spot. The prominent areas most commonly subjected to pressure must be inspected several times daily. Failure to observe these details may cause failure following any successful method of closure.

IRRADIATION INJURIES

Although the profession has known of the hazards associated with the use of x-rays and radium for many years,⁷ it has become strikingly

hands of those not properly trained in administration of irradiation therapy or in doctors themselves following prolonged and repeated use of the fluoroscope. Others, however, develop x-ray dermatitis and x-ray necrosis as an incidental by-product in the superficial tissues in the

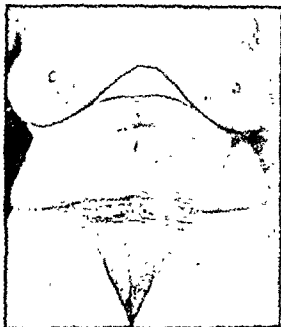


Fig. 569 —Deep x-ray ulcer of anterior abdominal wall following extensive therapy for pelvic carcinoma

necessary heavy therapy that is frequently given for deep or inoperable carcinoma. With the development of more powerful apparatus for this purpose, we will undoubtedly be faced with more incidental injuries of this type. And with the potential hazards of atomic warfare hovering over us, the potential survivors will naturally have extensive lesions in this category.

Irrespective of the source of the radiation injury, the pathology and symptoms produced are identical. The essential pathologic finding is a
 and irreversible obliterative process seen in the arteries,
 nutrition
 is even-

tually, which may finally result in ulceration and ultimate degeneration into carcinoma of the squamous cell type.

The lesions produce intense itching and pain which can never be relieved permanently until the damaged areas have been excised back to an area of good visible blood supply. Such removal produces a sudden

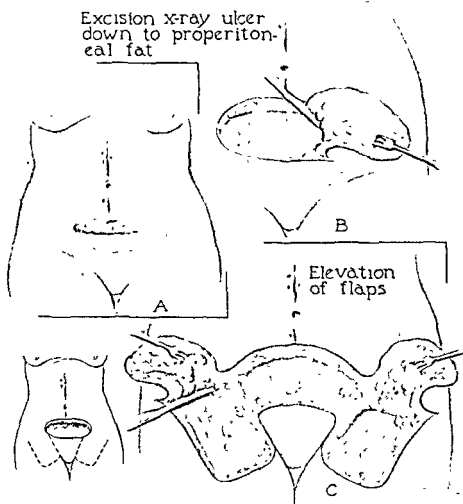


Fig 570.—Method of reconstruction in case shown in Figure 569. Ulcer excised back to an area of good blood supply.

and dramatic cessation of all subjective symptoms. Following excision, the open defect must then be covered with some type of skin graft.

Areas in which the damage is relatively superficial, and in which a subcutaneous fat pad or underlying muscle having an adequate blood supply remains, may be covered quite simply with a split-thickness skin graft. Where the damage is deep, and bones, joints, tendons and nerves have been exposed by the necessary excision of damaged tissues, the defect must be covered by skin and subcutaneous fat. This can

ordinarily be accomplished by the use of some variety of local rotation flap (Figs. 569 to 571), or if none is obtainable, with a direct or tubed pedicle flap taken from a distant point.

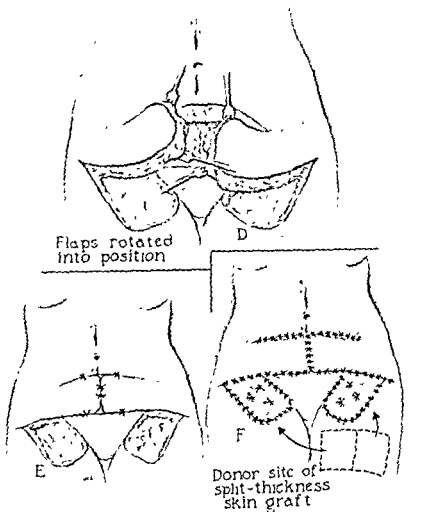


Fig. 571. — Stereotyped

It is imperative to emphasize that excision of the damaged tissues should be carried out early, i.e., as soon as the initial inflammatory reaction has subsided, and that the excision must be radical. Insufficient removal of damaged tissues will be followed by further breakdown incidental to an extension of the obliterative process in the blood vessels, and hence will result in loss of the overlying skin graft or flap.

SUMMARY

A discussion has been presented wherein a broader application of skin grafting procedures is utilized for the successful management of chronic leg ulcers, decubitus ulcers in paraplegics, radiation injuries, and in a trend towards the earlier repair of defects following thermal burns.

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SUTURE MATERIALS AND THEIR USE

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Precise hemostasis and coaptation of wound edges are essential to sound wound healing. All surgeons recognize the necessity of utilizing suture materials to achieve these ends. Unfortunately, the use of suture material in a wound is a direct violation of an established surgical principle against incorporation of foreign bodies in wounds. An inflammatory reaction is an inevitable consequence of foreign body implantation. The very technic of ligature implies the implantation of a foreign body and in addition leaves within the wound varying amounts of devitalized tissue. High frequency coagulation is so productive of tissue necrosis that it cannot qualify as a nonsuture method for hemostasis. It is to be regretted that human ingenuity has not developed a nonsuture technic for the control of hemostasis and the coaptation of wound edges.

ABSORBABLE VERSUS NONABSORBABLE SUTURES

Since the time of ancient Egypt surgeons have been concerned with both the technic and choice of material for suture. Modern surgery finds specific uses for both absorbable and nonabsorbable sutures. Catgut remains the universal choice for an absorbable suture. A greater variety of nonabsorbable sutures is in current usage. Silk is the animal product of choice. Cotton is the vegetable fiber of choice. Nylon is probably the most widely tested of the plastic products for buried sutures. Both steel and tantalum wires have strong advocacy.

As in any biologic experiment, the problem of comparative evaluation of these suture materials has been complicated by the presence of multiple variables. Most important are the amount of tissue trauma, the degree of bacterial contamination, the integrity of hemostasis and the amount of tension employed. In the avoidance of tissue trauma gentle handling of tissues alone cannot compensate for the damage done by undue exposure of the wound to the drying influences of the atmosphere, the use of strong antiseptic or irritating antibacterial agents or dissection with dull instruments. It is now quite generally recognized that technical perfection in wound management is more important than the choice of a suture material as a determinant of optimal wound healing. The descriptions of wound healing by Moynihan attest the validity of this contention.

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Students of the histology of wound healing have come to recognize optimal healing as "dry" healing. The aseptic inflammatory changes so characteristic of the dissolution and absorption of devitalized tissue, hematomas and foreign bodies are classified as "wet" healing. The survival and growth of bacteria within the wound leads to wound suppuration. The distinction between the aseptic inflammatory changes of wet healing and established wound suppuration has clinical importance in relation to the time required for ultimate wound healing. The technical objective, however, must be for dry healing because of the greater likelihood in the wet wound of the survival and growth of bacterial contaminants.

Catgut sutures constantly give rise to an inflammatory reaction resulting in the absorption of the catgut. The method of absorption is the same as for devitalized tissue. The process of wet healing delays fibroplasia and dissolves the fibrin which cements and fuses apposing wound edges. Impaired wound healing and dehiscence with sudden wound rupture or delayed incisional hernias are consequences of the extremes of this process. When catgut is replaced by nonabsorbable sutures, there is less demand for lytic enzymes and lessened incidence of hernia and wound separation. As has been emphasized above, however, it does not follow that dry healing is a constant accompaniment of all programs of wound management utilizing nonabsorbable sutures. The increment of advantage attributable to nonabsorbable sutures may be lost through neglect of the principles of

The fact remains that as demonstrated to possess this problem assiduously that meticulous handiwork lowered the incidence of both trivial and serious wound infection regardless of the suture material used, but the incidence of wound infection was always considerably less with silk than with catgut. It is further apparent from these studies that the incidence of trivial infections with catgut after a refined technic had been adopted was four times as great as the incidence with silk before improvements in technic of wound handling had been generally adopted. Subsequent studies in many clinics

It has even been demonstrated in the contaminated pharynx

tissue material, the choice of suture material, whenever there is ample justification for the ever-widening use of nonabsorbable sutures

American surgeons have been led to the adoption of nonabsorbable sutures largely by the observations of Halsted and Whipple upon silk. However, there has been a constant search for a better nonabsorbable suture than silk. As a result of experimental and clinical observations extending over a period of approximately ten years, the Tulane School of Surgery has a decided preference for the use of fine cotton sutures.

There can no longer be any question that cotton incites less inflammatory response than silk in wounds. The adaptability of commercially produced cotton thread to surgical purposes represented an economic advantage. Recently, however, the variability in tensile strength of commercial thread has become so marked as to constitute a cause for annoyance. If this defect continues, it may happen that cotton sutures will become as costly as silk.

The use of nylon was attractive because of the high tensile strength of fine threads. We believe that nylon tends to stretch and that the integrity of the ligature and the security of the knot are open to question. Further, nylon is apt to prove unsatisfactory because of the occasional occurrence of sensitivity to the plastic material.

Undoubtedly there is less inflammatory reaction to steel or tantalum wire than to any other available suture material. Even though it is practically inert in tissues, it has many objections. It is a bulky suture and difficult to handle, with the result that considerable attention must be devoted to the avoidance of tension. Secondary surgical intervention in a wound previously sutured with wire is open to objection because of the likelihood of puncture wounds to the surgeon's gloves or fingers and the dulling effect upon sharp surgical instruments in contact with metallic sutures. Radiopacity is another undesirable feature. It is believed that these objections are contraindications to the routine use of wire for all purposes but are not sufficiently great to prevent its use for special purposes.

There should be general agreement with the conclusion that the use of nonabsorbable sutures with strict adherence to the principles of gentle handling of tissues will lead to the greatest incidence of dry wound healing. It is of some importance that for years plastic surgeons, ophthalmologists and neurosurgeons have advocated the use of nonabsorbable sutures. Attention to these technical details is essential to success but will not compensate for neglect of problems in nutrition or general physiology important for the ultimate integrity of wound healing. It should be recognized that all types of sutures retain a usefulness for specific situations in the hands of individual surgeons.

OUTLINE OF SUTURE PRACTICE AT TULANE

Isolated opinions as to the indications for the use of various sutures are interesting topics for discussion but hardly the basis for major controversy. The following broad program currently guides the usual practice of the surgical group at Tulane.

Closure of Abdominal Wounds.—Interrupted cotton sutures are used for the closure of all layers, including the peritoneum. Everting mattress sutures are preferred for the closure of the peritoneum in vertical incisions, but simple closure is usually practiced in transverse incisions. Through and through retention sutures are not used to reinforce a layer closure. In general, retention sutures are used only for the closure of

wounds in debilitated patients and after wound dehiscence. Various technics have been tried to avoid wound dehiscence, but no method of suture has completely obviated the problem. The most important factor in the current low incidence of wound dehiscence appears to have been the adoption of the transverse incision in the upper abdomen.

Fascial Suture.—The many advantages of interrupted nonabsorbable sutures in the repair of hernias have led to their adoption for all instances of fascial approximation. This principle has found such advocacy that interrupted cotton sutures are now used routinely in the repair of episiotomy and perineal relaxation in the department of obstetrics and gynecology. It is especially desirable to have minimal reaction and maximal tensile strength in sutures placed in collagenous tissues. Bunnell's wire pull-out suture for certain types of tendon repair seems especially sound. The use of nonabsorbable sutures in the repair of bone has been largely replaced by bone grafts, screws or plates because of the improved fixation afforded.

Hemostasis and Blood Vessel Anastomosis.—It is a mark of the accomplished technician that he resorts frequently to the use of the stitch ligature for hemostasis. As originally urged by Halsted, it is frequently practical to use a stitch ligature to control a major vessel with suture material of small size, incorporating a minimum of tissue within the tie. Bleeding due to the inadvertent puncture of a blood vessel is easily controlled by a slight twist of the hemostat. An added advantage of the transfixion suture is the greater security of the ligature.

In the suture method of anastomosis of major blood vessels and the repair of aneurysms, we continue to express a preference for interrupted everting U-sutures of nonabsorbable material. Adoption of a continuous suture for these purposes is a concession to rapid accomplishment of the union. It is interesting to speculate upon the possible difficulties which might arise in later life if continuous nonabsorbable sutures are used in the anastomoses and shunts in young children with cardiovascular anomalies.

Gastrointestinal Anastomosis.—The peculiarities of the blood supply to the gastrointestinal tract from the esophagus to the rectum are such that an extremely strong case may be made out for the routine adherence to interrupted seromuscular sutures. Peritonitis does not result from the transient fecal contamination incident to the opening of the properly prepared bowel, but from the persistent fistulous leak at the anastomotic site. With precise serosal apposition and avoidance of hemostatic continuous sutures in the outer layers, the immediate and continued integrity of the anastomosis is assured. The same principle may be extended to the use of interrupted sutures for mucosal approximation. This seems to us to be especially important in the esophagus and colon. The more widespread adoption of open anastomoses since the advent of chemotherapy lends itself to the exploitation of the interrupted suture technic and is less apt to result in stricture or stenosis.

In general, we have adopted the principle of obtaining a broad area of serous approximation by two layers of sutures in all anastomoses below the diaphragm. In esophagogastric anastomosis a third outer layer of sutures is frequently placed to align and position the segments for anastomosis, but the actual anastomosis is accomplished with two layers of interrupted nonabsorbable sutures.

Sutures in Lobectomy and Pneumonectomy.—For many years it was customary to repair the visceral pleura with atraumatic catgut sutures placed through the pleura and some of the lung substance. As a matter of convenience in the course of operation, the ever available interrupted cotton suture has gradually replaced the catgut suture. No difficulties have been encountered in consequence of this change. The bronchus is closed routinely with cotton sutures.

One ligature and two stitch ligatures are used for the management of the hilar vessels. The stitch ligatures are introduced proximal to the simple ligature and at cross axes to each other.

Catgut Sutures.—The greatest usefulness of catgut is for the apposition of mucous surfaces within the gastrointestinal tract. If hemostatic continuous sutures are to be employed for gastroenterostomy, as is often done in the mucosal layer, catgut avoids the pendulous loop in the lumen of the bowel. It is also felt that a mucosal layer of catgut and a seromuscular layer of nonabsorbable sutures insures the intraluminal evacuation of perianastomotic abscess between the two layers of sutures.

In deep sutures through parenchymatous organs, such as the liver or breast, catgut is preferred. A considerable length of suture is involved and the danger of permanent ductal constriction is to be avoided.

Catgut is also used for the repair of mucous membranes in the urinary bladder and the biliary tract where it is feared concretions might form about a nonabsorbable suture.

Closure of Wounds with Dead Space or Contamination.—It is commonly stated that drains should not be used in association with non-absorbable sutures. We find this to be a fallacy and do not hesitate to drain a wound closed with cotton, nor is there any hesitancy to close a contaminated wound with cotton sutures. It occasionally happens that cotton sutures will be extruded or require removal with a crochet hook. This is also true of catgut and silk.

Repair of Large Defects.—The use of autogenous grafts of fascia, as introduced by Gallie, has continued to find occasional usage for the repair of fascial defects. It is quite apparent that this material is inert and remains as a living suture. As much cannot be said for the prepared fascia of animal origin which is preserved in various solutions. More recently there has been an attempt to utilize buried skin grafts for similar purpose. It is too early to assess the virtue of buried skin grafts, but an interesting extension of the concept has been enunciated for the closure of tracheal wounds. Further experience and observation is necessary for the final appraisal of these procedures. The substitution of tantalum mesh for reparative procedures in large fascial defects has

been advocated, but has not become universally practiced as yet. In general, the use of large quantities of foreign body in a wound is to be deplored.

SUMMARY

Some of the more important concepts governing the choice and technic of sutures and ligatures have been discussed. Current practices in the surgical department of Tulane University have been reviewed.

SOME MODERN GENERAL ANESTHESIA TECHNICS

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MANY interesting changes in anesthesiology have taken place in the last decade. Only one outstanding agent, curare, has been added to the anesthetist's armamentarium. However, new concepts and technics for utilizing anesthetic agents have been developed. It is the purpose of this paper to outline certain acceptable technics with some anesthetic agents.

Dosage of other than anesthetic drugs is fairly well established. The dose of most drugs is usually given in units, grains or milligrams. This is not the case with substances used for anesthesia. Here one is dealing with very potent drugs in doses which would easily be lethal if proper precautions were not taken. The only available indicator of proper dosage is the patient himself. As each patient differs in his reaction to an anesthetic drug, modern anesthesiologic technics must embody careful control of each anesthetic procedure according to the patient's response.

PRESENT TECHNICS WITH PENTOTHAL SODIUM

A large volume of literature exists concerning this drug. Intravenous anesthesia has become synonymous with pentothal sodium. Its scope of usefulness has become ever broader, and it has a range of usefulness which was not dreamed of a decade ago. It has become the agent of choice in a large number of surgical operations. It is used for many procedures in general surgery, orthopedics, gynecology, plastic surgery and urology. It is used extensively but not accepted universally for certain procedures in neurosurgery, thoracic surgery, proctology and pediatric surgery.

In the effort to make the anesthetic experience less terrifying and more comfortable to the patient, pentothal sodium has been used as an induction agent for inhalation anesthesia. This use is entirely justified, for one can accomplish a pleasant induction with no increased risk to the patient and with very little inconvenience to the anesthetist. This has its most useful application in children and in patients who are apprehensive and upset. In the adult the usual dose of pentothal sodium when preoperative medication includes morphine is 4 to 8 cc. of a 2.5 per cent solution. The purpose here is not to induce anesthesia with the pentothal sodium, but to obtain amnesia so that the patient does not remember the mask being placed on his face. A dose larger than necessary to

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accomplish amnesia may cause depression of respiration with delay of the induction of anesthesia.

With local or regional anesthesia, pentothal sodium may be equally useful as a supplement in the event that the patient is very restless and uncooperative. There are limitations here when the local anesthetic agent is given because a general anesthetic agent may be contraindicated in the presence of a full stomach. Also one should not use pentothal sodium when the local anesthetic agent is chosen because the operation is intimately concerned with the airway as in laryngectomy or pharyngoesophageal diverticulectomy.

The best results are obtained with pentothal sodium when it is combined with inhalation of a mixture of nitrous oxide and oxygen. This may be in the ratio of 50:50, or higher concentrations of nitrous oxide may be used. It is important to realize that with higher concentrations of nitrous oxide total flow rates must be kept relatively high. Crowley and his associates² have shown that the inspired oxygen will fall below 20 per cent if an 80:20 nitrous oxide-oxygen mixture is metered into the machine in amounts less than 6 liters per minute. A total flow of 2 liters per minute is very satisfactory if the ratio is 50:50. In this latter case one provides an analgesic mixture which contains more than 40 per cent oxygen.

There is a group of surgical procedures for which minimal anesthesia with pentothal sodium may be very suitable. Included under this heading are encephalography, certain types of dental extractions and changing painful dressings. The usual performance of encephalography with the patient under local anesthesia is associated with severe pain in the head. A small amount of pentothal sodium (approximately 500 mg.) gives complete relief while the procedure is carried out. A dental extraction which will be short may be done with the patient under pentothal sodium anesthesia. Frequently 6 to 8 cc. of a 2.5 per cent solution (150 to 200 mg.) will give sufficient analgesia for an extraction. If several teeth are to be removed and pentothal sodium is to be used, the procedure of choice is to cocainize and intubate the patient.

Precautions.—The most important principle in pentothal sodium anesthesia is to maintain a completely free and unobstructed airway. Most of the contraindications and complications involve this factor. Respiratory depression must be avoided and the means of treating it effectively, that is, oxygen and apparatus to render efficient artificial respiration, must be at hand. Obviously it is more satisfactory to avoid an overdose than to have to treat it.

Anoxia during deep pentothal sodium anesthesia is likely to occur despite a patent airway. Etsten and Himwich³ found a definite to severe fall in the arterial oxygen saturation in ten of eleven patients when subjected to deep (stage III, planes 1 to 3) pentothal sodium anesthesia. Their data verify the well established clinical finding that an increased tension of oxygen should be administered to each patient undergoing pentothal sodium anesthesia. Further, if one can supplement pentothal

sodium with a nitrous oxide-oxygen mixture and thus reduce the amount of respiratory depression by giving less pentothal sodium, the hazard of anoxia is decreased. As with any anesthetic agent, the immediate postoperative period following pentothal sodium anesthesia is a critical time for the patient. He may be removed from an oxygen-enriched atmosphere to room air in a depressed condition. Further, anoxia may result from imperfections in the airway. These dangers may be minimized if the patient is responding before leaving the operating room. If he is not, he must be watched carefully until he responds and respirations are normal.

CURARE

Curare is truly a remarkable drug. New drugs usually follow a pattern when they are introduced: first a wave of enthusiasm, then one of reaction and finally an adjustment to their proper place in the physician's armamentarium. Curare is still in the first stage and is being used enthusiastically by many anesthesiologists. However, it has been used

TABLE 1
INCREASING USE OF CURARE AT THE MAYO CLINIC
FROM 1943 THROUGH 1948

Year	Cases
1943	23
1944	48
1945	439
1946	754
1947	1,402
1948	3,431

with such excellent results in so many cases that its important position in anesthesiology is assured. On the other hand, it is true that it is not wholly accepted by some who consider it the crutch of the less expert. Table 1 illustrates the increase in the number of cases for which it has been used at the Mayo Clinic.¹¹

Curare exerts its effect by blocking the transmission of impulses at the myoneural junction. Its action on the central nervous system is not completely elucidated. However, when used during anesthesia, it must be given only for muscular relaxation. An anesthetic agent per se must be relied upon to obliterate painful stimuli from the operative site.

Curare and Cyclopropane.—Griffith and Johnson⁷ first reported on the use of curare in conjunction with cyclopropane. This remains a very useful combination. A satisfactory technic for intra-abdominal operations is to anesthetize the patient with cyclopropane to plane 1 or 2, then intubate him, and give the curare five minutes before the peritoneum is opened. The dose of curare depends upon the operation, the physical state of the patient and his response. It is wise to give 1 cc. of d-tubocurarine chloride (3 mg. per cc.) and observe its effect. Usually 4 to 5

cc. will give excellent relaxation. In approximately thirty minutes, more curare may be needed. A smaller dose (3 to 9 mg.) will give good relaxation. If the procedure is long, an additional 1 to 3 cc. (3 to 9 mg.) may be necessary to permit a strong closure of the peritoneum and fascia. It is desirable to give the last dose of curare thirty minutes before the patient is removed from the operating room, for then the patient will quickly respond and the danger of serious postoperative anoxia will be avoided. The change from inspiring a high oxygen tension to room air and being less closely observed sets the stage for a serious accident if a patient leaves the operating room in a depressed state.

Curare and Pentothal Sodium.—This has become a widely used combination because of the ease of induction and the comfort to the patient. Curare provides the relaxation, the lack of which is the outstanding disadvantage of pentothal sodium anesthesia. Baird and his associates¹ recommend the use of pentothal sodium and d-tubocurarine chloride mixed in the same syringe (500 mg. of pentothal sodium and 15 mg. of d-tubocurarine chloride in 20 cc.). We prefer to administer these two agents in separate syringes. For many procedures, and for some patients, satisfactory relaxation may be obtained with a relatively small dose of curare. If the two drugs are given separately, curare is administered only when it is needed for relaxation.

Nitrous oxide and oxygen in a 50:50 mixture are administered routinely with the pentothal sodium and curare. If the operation is long or calls for maximal relaxation, or if the patient is to be in Trendelenburg position, an endotracheal tube is recommended. Thus a patent airway is assured and if, as frequently occurs, moderate to severe respiratory depression develops, the tidal exchange can be maintained by intermittent manual pressure on the bag.

Curare and Ether.—It is rare that one intentionally combines curare and ether. However, if relaxation is unsatisfactory in certain cases, a small dose of curare (3 to 9 mg. of d-tubocurarine chloride) will convert a difficult situation into a very satisfactory one. The curare must be given cautiously or an overdose will result. Ether itself has curariform properties, and prolonged respiratory depression may result if an overdose of curare is given. Furthermore the smaller dose of curare will accomplish equally good relaxation with ether as will a larger dose with cyclopropane or pentothal sodium.

Curare and Nitrous Oxide.—Harroun and her associates² have reported good results with curare and nitrous oxide anesthesia in thirty-eight patients. The margin between an adequate and an insufficient inspired oxygen tension is so slight that this combination is not recommended.

Uses.—Curare has found its greatest field of usefulness in providing relaxation for *intra-abdominal operations*. If it is administered in sufficient dosage, the relaxation is as good as, or better than, that provided by spinal anesthesia. The absence of the nausea and retching that occasionally occur with spinal anesthesia makes for excellent working condi-

tions. The surgeon is able to obtain excellent exposure and presumably can do a better job in less time than he could when only mediocre relaxation was provided. Pelvic operations by the abdominal route are likewise facilitated when excellent relaxation is provided by curare. For pelvic operations from below, curare may be quite useful, especially in closing the peritoneum after vaginal hysterectomy. Here the dose is usually minimal (3 to 9 mg. of d-tubocurarine chloride).

In *urologic surgery*, curare is also helpful. It provides good relaxation for operations on the kidneys and ureters. It apparently has no deleterious effect on renal function.

Curare has a definite field of usefulness in *orthopedic surgery*. The relaxation in cases in which pentothal sodium is used may be greatly improved by administering a moderate dose of curare.

Curare is invading the field of *thoracic surgery*, and here it is usually combined with pentothal sodium. The purpose of the curare is to quiet the respiratory movements. Hence, when it is used under these circumstances, augmentation of the respiratory exchange is important to insure oxygenation and removal of excess carbon dioxide. Furthermore, the dose of curare is smaller than that for intra-abdominal operations.

At the Mayo Clinic a combination of pentothal sodium and curare is used for direct suspension *laryngoscopy*. The larynx is cocainized with the patient awake. It is important to have the patient well anesthetized before the surgeon begins his manipulations, or laryngospasm is likely to occur. Oxygen is insufflated by means of a nasopharyngeal airway. As the curare takes longer than the pentothal sodium to exert its effect, 2 to 3 cc. (6 to 9 mg. of d-tubocurarine chloride) is given slowly. Then the patient is anesthetized with the pentothal sodium. A fairly large dose is required. Frequently 1 or 1.5 gm. of pentothal sodium is necessary for a relatively short procedure. A total of 5 cc. of curare is often necessary. The critical aspect of this technic is that the patient is frequently depressed almost to the point of apnea before the surgeon can work without troublesome laryngeal reflexes. Also one cannot give as efficient artificial respiration as when he has an airtight fit between the anesthesia apparatus and the patient's lungs. Hence the anesthetic agent must be administered very judiciously. The redeeming features are that the procedure is short, and the operating surgeon can hold the cords open and oxygen can be insufflated into the lungs.

A similar technic is employed for *esophagoscopy*. Preliminary medication includes moderate doses of morphine, atropine or pentobarbital sodium. Here the dose of curare and pentothal sodium is relatively small. A total of 9 mg. (3 mg. per cc.) of d-tubocurarine chloride and 500 to 750 mg. of pentothal sodium is usually adequate. Again the examination is usually short and probably the greatest hazard lies in the immediate postoperative period. The patient must be watched closely until he is breathing normally and can be easily aroused.

One of the first clinical uses for curare was to control convulsions produced by *electroshock therapy*. It still is very useful for this purpose.

A relatively large dose (5 to 7 cc. [15 to 21 mg. of d-tubocurarine chloride]) is necessary. Usually 5 to 10 cc. of 2.5 per cent solution of pentothal sodium is used to produce amnesia for the entire experience.

Precautions.—The rules for administering curare with safety are simple; yet they must be adhered to. Curare is an extremely potent substance and must be treated as such.

1. Each patient must be treated as an individual case. The effective dose for one patient may be a toxic dose for the next.

2. Respiratory depression or paralysis must be expected in certain cases. Hence it should be prepared for in every patient. The means of administering effective artificial respiration must be at hand at all times. Reliance must be placed upon efficient artificial respiration rather than on prostigmine or any analeptic drug. If one anticipates respiratory depression in a given case, an endotracheal tube should be inserted to permit easy artificial ventilation without dilating the stomach.

3. Respiratory depression in the immediate postoperative period is an all too frequent and serious complication of curare anesthesia, particularly of the pentothal sodium-curare combination. This is best avoided by the discriminate administration of both the pentothal sodium and curare. One should anticipate the need for relaxation for closing the peritoneum and give the curare so that its effect will be gone by the time the operation is completed. Likewise little or no pentothal sodium should be given for the last fifteen to thirty minutes of the operation, and anesthesia should be maintained by means of nitrous oxide and oxygen.

4. Curare must not be given to a patient who has myasthenia gravis, and it probably should not be given to a patient who has asthma.

5. Neostigmine in doses of 1 to 3 mg. (2 to 6 cc. of 1:2000 solution) is an effective antidote. But again it should be used only as a supplement to efficient oxygen therapy.

Complications.—1. Respiratory depression and paralysis after use of curare have already been discussed.

2. Bronchospasm has been reported in animals² and in humans.^{5, 6, 11} Although most authors report the possibility of bronchospasm, it is an infrequent complication and there have been no reported deaths.

3. Hypotension is likewise reported as occurring in animals and humans. However, it likewise is not a frequent or serious complication if due to the curare *per se*.

4. Idiosyncrasy has been reported. One patient could not be revived after administration of 15 mg. of d-tubocurarine chloride and 0.5 gm. of thiopentone, and another patient went into respiratory arrest on three occasions after receiving doses of d-tubocurarine chloride of 6 mg., 5 mg. and 2 mg. respectively.⁶ This latter patient showed no evidence of myasthenia gravis.

5. Patients who have myasthenia gravis tolerate small doses of curare very poorly. If curare is inadvertently administered to such a patient, immediate and aggressive resuscitative measures must be instituted.

ENDOTRACHEAL ANESTHESIA

The use of the endotracheal tube is becoming increasingly important in modern anesthesia. It is used mainly with agents producing general anesthesia, including cyclopropane, ether, pentothal sodium and the pentothal sodium-curare combination. Endotracheal anesthesia offers several significant advantages to surgeon, anesthesiologist and patient and involves few disadvantages. The foremost advantage is the removal of respiratory obstruction. It can relieve or prevent laryngospasm, and provides a completely patent and unobstructed airway from the anesthesia apparatus to the trachea. Respiratory effort, which is frequently strenuous, is now easy, and respirations are smooth and quiet. Of almost equal importance is the role of the endotracheal tube in preventing the aspiration of stomach contents during gastric operations or blood and debris during operations on the mouth, nose or sinuses.

In operations around the neck, face and head, not only is respiration unobstructed but the anesthetist is removed from the operative field. He is out of the surgeon's way and the latter no longer runs the risk of asphyxiating his patient to accomplish his operative objective. Further, an aseptic technic is more feasible when the anesthetist is out of the operative field. Another advantage is that in the event that pus, blood or mucus accumulates in the tracheobronchial tree, it may be readily removed by aspiration through a catheter passed down the endotracheal tube. Furthermore, the position of the patient may make the maintenance of a patent airway difficult. The prone position is a frequent offender, and the use of an endotracheal tube in such cases is strongly recommended. If it is anticipated that respirations will be greatly depressed, as frequently happens in using cyclopropane, cyclopropane and curare, ether and curare, or pentothal sodium and curare, an endotracheal tube will permit easy augmentation of respiration. Hence, another important advantage of an endotracheal tube is that it permits easy, efficient and effective artificial respiration. During operations on the open thorax, an endotracheal tube is essential in permitting easy control of the intrapulmonary pressure.

The disadvantages of endotracheal anesthesia are few. The most important one may be that the person attempting intubation is not skilled and experienced with the method. The number of difficult intubations and complications will vary inversely as the skill of the anesthesiologist. Trauma to the lips, teeth, tongue, pharynx and larynx can be avoided with good judgment and gentleness. Easy and nontraumatic intubation depends on relatively deep anesthesia. Hence the induction is likely to be longer than when endotracheal anesthesia is not used. Gillespie,⁴ in his excellent monograph *Endotracheal Anesthesia*, stated: "The incidence of minor respiratory complications, such as cough or a slight soreness of the pharynx, is probably somewhat higher after endotracheal anesthesia."

Technic.—Intubation may be performed by the oral or the nasal

route depending upon the surgical requirements, the local conditions in the patient's nose and mouth and the preference of the anesthetist. In general, we prefer the oral route but we use nasal intubation when it is specifically indicated. Only rarely is it impossible to pass an endotracheal tube by the oral route, and then one does not worry about complications from nasal intubation except recurrent sinusitis. The most serious complication is severe epistaxis concomitant with a failure to pass the tube through the cords. *The technique of oral and nasal intubation is described in detail by both Gillespie⁴ and Lundy.¹⁰* The latter described the insertion of the laryngoscope as follows:

The anesthetist should remove the pillow from under the patient's head and tilt the chin upward with his right hand. According to Magill's technique, a strip of adhesive plaster 1 by 2 inches (2.5 by 5 cm) is applied to the upper central incisor teeth and the upper lip. The adhesive plaster to some extent protects the teeth against roughening by the metal blade of the laryngoscope. The anesthetist uses his right thumb to roll back the patient's lower lip. The tip of the blade of the laryngoscope is inserted over the lower teeth without pinching the tongue. If the head is not sufficiently tilted, an assistant may tilt it. The anesthetist must see to it that the patient's tongue is forced over into the left side of the patient's mouth or into the left cheek. *In this way the tongue will lie behind the laryngoscope so that it does not interfere with the anesthetist's vision.* No strong effort is to be made with the left hand in attempting to force the introduction of the laryngoscope. It is simply held firmly enough so that its direction can be maintained and so that it will stay fairly well in the midline of the mouth or to the right of the midline. This may be difficult when there are no teeth unless a large blade is used. In general, however, it is easier to insert a laryngoscope when there are no teeth than when there are teeth.

When a fifth of the blade has been introduced, the anesthetist should see to it that the tip of the laryngoscope is not striking the hard palate. This injury must be avoided and can be by the anesthetist's introducing his right thumb so that it rests on the tops of the back teeth in the right lower jaw. The fingers of the anesthetist's right hand then should grasp the right lower border of the mandible. With the jaw gripped in this fashion it is drawn up so that the jaw is pulled up onto the laryngoscope and at the same time the anesthetist's left hand forces the laryngoscope into the pharynx. This motion is similar to that of a man drawing on a riding boot, that is, he partly pulls the boot on and partly shoves his foot into it.

When the blade of the laryngoscope is inserted a half to two-thirds its length, the base of the tongue then can be seen, and next the epiglottis is visualized (Fig 572, a). At this point the anesthetist must reach a bit further and direct the laryngoscope toward but not against the posterior wall of the oropharynx (Fig 572, b and b'), and then bring it forward so that the tip of the laryngoscope will press the epiglottis against the base of the tongue and leave the vocal cords exposed to view (Fig 572, c). In the introduction of the laryngoscope into the mouth, it is important that the anesthetist does not look through the laryngoscope all of the time, he should also look occasionally at the lips, teeth, tongue, palate and so forth at intervals.

As soon as the vocal cords are brought into view the anesthetist holds the laryngoscope firmly with the left hand but does not pry against the upper central incisor teeth [or he may pry gently in difficult cases]. Rather, he lifts the laryngoscope upward without bearing much weight on the patient's upper teeth.

The tube is inserted through or just to the right of the laryngoscope blade and should pass the cords when they are in the phase of greatest abduction (Fig. 573).

Nasal intubation may be done blindly or by use of the laryngoscope to visualize the location of the endotracheal tube and guide it toward the opening of the glottis. Blind intubation is performed by having the patient in a supine position with the face parallel to the floor. The tube is inserted gently but firmly until it lies in the pharynx. As it is advanced toward the larynx one listens for the tubular breathing. If this continues until the full length of the tube is inside the patient's nose, the tube is probably in the trachea. One can substantiate this by

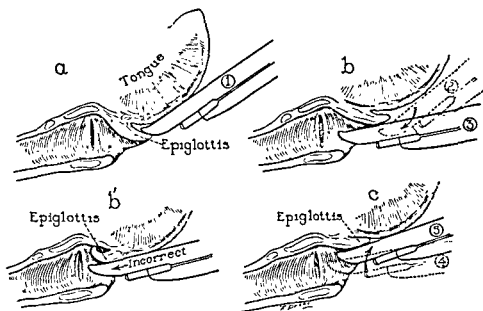
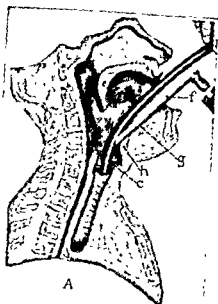
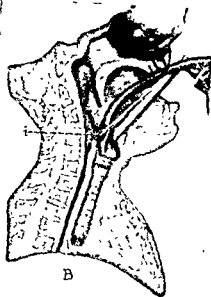


Fig. 572.—
laryngoscope
are supported
laryngoscope is advanced from *a* without depressing the blade as in *b*; *c*, the epiglottis is picked up by the laryngoscope which then supports it, the tongue and the jaw so that the right hand is released. (From Lundy, J. S. *Clinical Anesthesia: a Manual of Clinical Anesthesiology*.)

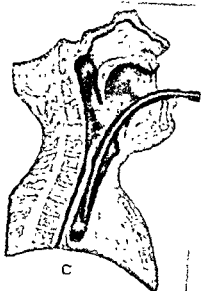
closing the mouth and opposite nostril. If respiration is still unimpeded through the endotracheal tube, the tube is in the trachea. If the tube does not enter the pharynx and i
pharynx is explored quickly with several gentle thrusts. The patient's head may be turned from one side to the other. Also flexion of the head may facilitate intubation. If, after several gentle attempts, intubation is not accomplished, one should insert a laryngoscope and pass the tube under direct vision. A Magill forceps may be of great assistance in directing the tube into the trachea (Fig. 574).



A



B



C

Fig 573 — Oral intubation A, Laryngoscope and tube; f, laryngoscope moves
 a tongue and b on side.

the larynx has been compressed by an intrathoracic tumor (goiter). Note the difference in the placement of the tubes here as compared with that shown in Figure 574, D. (From Lundy, J. S.: *Clinical Anesthesia a Manual of Clinical Anesthesiology*.)

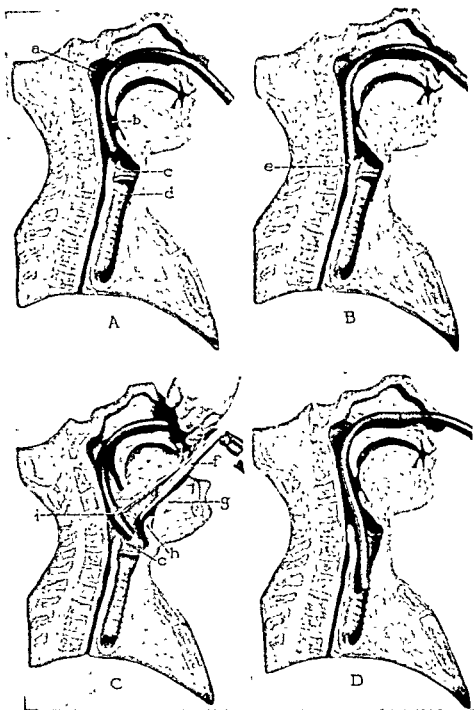


Fig. 574.—Nasal intubation A, The tube through the nose and *a*, nasopharynx, and extending well into *b*, the oropharynx; *c*, vocal cords, *d*, trachea. B, Tip of tube enters *e*, esophagus C, *f*, Laryngoscope, inserted through opened mouth, exposes *c*, glottis and vocal cords, by moving *g*, the tongue, and *h*, epiglottis, out of the line of vision; *i*, Magill forceps grasps the tube near the tip and directs it into the glottis. D, Nasal tube properly placed, the tip lying midway between the glottis and the bifurcation of the trachea. (From Lundy, J. S.: Clinical Anesthesia: a Manual of Clinical Anesthesiology.)

FLUID AND ELECTROLYTE BALANCE

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THIS paper presents a brief outline of some fundamental concepts of fluid and electrolyte balance, with a more detailed discussion of the aberrations encountered in the care of the surgical patient. Therapeutic correction of salt and water deficits is related to the patterns of imbalance commonly observed, with special consideration of the role of the potassium ion.

EXCHANGES OF SALT AND WATER IN THE NORMAL HUMAN ORGANISM

The normally functioning organism maintains its water and salt content with apparent ease. The kidney is an organ of prime importance in conserving water and salt, excreting excesses of either one or both as necessary, and in ridding the body of metabolic end products.

The skin and respiratory tract exchange respectable amounts of water with the external environment in the process of heat dissipation. About 25 per cent of the body heat is removed in the evaporation of 0.5 to 1 liter of water from the skin each day.^{1, 2} The remainder of the heat load is transmitted to the circumambient areas through radiation, conduction and convection. An additional 0.5 to 1 liter of water is put out each day in the expired air.³⁻⁵

Within itself the organism rapidly exchanges large volumes of solutions in the process of alimentation, transfer of metabolites and in the metabolic processes per se.^{6, 7} The available fluid is used most efficiently. About 7 liters of secretion are put out by the digestive tract, and an additional 2 liters of water taken in with the diet, yet the feces contain only 100 to 150 ml. of water. The renal glomeruli filter roughly 160 liters of fluid into the tubules each day, the tubules retain the necessary water and salt, excrete some additional unwanted ions, and the daily urine output is only 600 to 1500 ml.

Maintenance of this dynamic equilibrium is dependent upon an adequate circulation. The term normal blood volume implies not only adequate hemoglobin for oxygen transport, but also adequate water, protein colloids and crystalloids to assure correct osmotic gradients. The plasma volume is dependent upon the reservoir of extracellular fluid, among other things.⁸⁻¹⁰ This space between the cells must be filled with water and salts maintaining pressure relationships, "buffering"

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sudden changes in circulating fluid and exchanging substances with the intracellular space.

The Importance of the Plasma Protein.—Protein stores in general, and plasma proteins especially, have a vital role in establishing these normal relationships between intracellular and extracellular fluid.¹¹ Jones and Eaton first reported that hypoproteinemic edema in patients undergoing gastro-intestinal surgery, especially operations involving the stomach and duodenum, is not uncommon.¹² It is not enough that the plasma protein in the circulation be adequate, for there must also be sufficient reserve stores of protein. Protein and electrolyte are complexly interdependent, protein being the major contributor to the osmotic pressure of the blood stream, and electrolyte, specifically the cation potassium, being the active agent in intracellular tonicity. Protein as well as crystalloid circulates outside the vascular channels and appears in the collected lymph.¹⁶⁵

The Regulation of Electrolyte.—The body economy retains salt, depending on the dietary intake. The healthy person in a temperate climate puts out about 3.5 to 12 gm. of sodium chloride daily.¹³ Urine contains 3 to 11 gm., feces 0.2 gm., and about 0.2 to 0.4 gm. passes through the skin. If, however, the person is taking a diet very low in salt, only minute amounts will appear in the urine. The dietary intake of salt has little or no influence on the salt loss through skin.

The skin is not primarily an excretory organ. At moderate temperatures water passes through by osmosis, and under these conditions the loss of salt is usually less than 0.5 gm. per day.¹⁴ At high temperature sweat glands become active, pouring out a hypotonic solution containing sodium chloride, potassium, lactic acid and sulfates.^{15, 16} Under extreme conditions the sodium chloride loss may be as high as 2 gm. an hour temporarily.^{17, 18} However, maximal sweating over long periods of time leads to adaptation of the sweat glands with production of a fluid containing about 15 miliequivalents of sodium chloride per liter and having a pH of not less than 4.^{19, 20}

The Work of the Kidney.—Data accumulated by Richards,^{21, 22} Pitts et al.,²³ and many others have thrown light on the crucial work of the kidney. The tubules selectively reabsorb needed ions.²⁴ They also excrete acid, yet conserve fixed base, by adjustment of the phosphate and carbonate buffers. When more acid is excreted, tubular cells are apparently able to replace fixed base with hydrogen ion, probably obtained from carbonic acid.²⁵⁻²⁷ The tubules can also secrete potassium, among other substances.²⁸ The glomerular filtration rate and tubular function are circulation-dependent. Shunts exist within the kidney by which blood is selectively directed.

Craik²⁹ has obtained evidence of two types of circulation by which control of water excretion may be achieved. He describes superficially placed nephrons in the outer two-thirds of the cortex with short, narrow limbs in Henle's loop. This portion is supplied by a vascular bed with high peripheral resistance. In contrast, deep in the inner one-third of

the cortex are nephrons with long loops and a vascular bed of low peripheral resistance. This might permit the kidney to expose glomerular filtrate to a short or long absorbing surface, depending upon whether a small amount or a large amount of water is to be returned to the body.

EXCHANGE UNDER PATHOLOGIC CONDITIONS

Alterations from the normal pattern appear because of the loss of abnormally large amounts of water, or of salt, or of both water and salt in varying proportions.³⁰

Dehydration and Salt Depletion.—The need for replacement of salt solution in the case of the dehydrated patient is well recognized³¹⁻³⁴; however, there is more to this particular problem than simple replacement. In addition to a water deficiency there is an electrolyte deficiency whose pattern depends upon the route by which the patient has lost abnormal amounts of fluid. The patient with pyloric obstruction will vomit gastric juice, thus losing more chloride than sodium, and becoming alkalotic.³⁵ A jejunal fistula discharges fluid that resembles mammalian Ringer's solution in its electrolyte composition. A patient with such a lesion will show dehydration and salt depletion in the form of a reduction in total salt concentration.³⁶⁻³⁹ Loss of fluid low in the ileum, where secretions contain an excess of bicarbonate over chloride, will result in acidosis as well as dehydration.

It is illuminating to consider for a moment single types of depletion patterns, which can be produced experimentally. More detailed observations of fluid and ion shifts can be made in these cases, whereas it is not practical or actually impossible clinically. The work of Danowski, Winkler, Elkinton et al.⁴⁰ contains examples of various types of depletion produced in dogs.

Acute sodium chloride depletion can be produced by intraperitoneal injection of 5 per cent glucose in water and subsequent withdrawal after equilibration of the intraperitoneal fluid with the body fluids. Under such circumstances the plasma volume, blood pressure and cardiac output drop. Plasma protein begins to leave the circulation, and the animal goes into peripheral circulatory collapse.

On the other hand an intravenous injection of a solution consisting of 10 per cent urea and 5 per cent glucose in water produces a copious diuresis, and as a result acute water deprivation. These animals, while sustaining a drop in extracellular fluid equal in amount to that seen in the first experiment, do not suffer peripheral vascular collapse. Although plasma volume, arterial blood pressure and cardiac output decrease somewhat, little or no plasma protein disappears from the circulation.

Animals suffering from salt depletion respond promptly to the administration of intravenous saline, whereas the administration of 5 per cent glucose in water causes dilution of body fluids and eventual death from water intoxication, if the fluid administration is continued.⁴¹ The

beneficial effects of saline are attributable in part to the return of protein to the circulation. If salt-depleted animals are treated with small amounts of colloid and just enough salt to replace but 25 per cent of the initial salt deficit, they improve just as rapidly as if given the full amount of saline alone.⁴²

Dogs depleted of both salt and water go into a very rapid collapse.⁴³

Irreversible Tissue Damage following Dehydration.—Depletions of small amount and brief duration do not materially injure the organism. When such imbalance becomes more marked and persists for longer periods of time, the organism suffers irreversible tissue damage following dislocation of intracellular fluid and ions and the resultant circulatory collapse.

Van Slyke⁴⁴ has shown that dehydration leads ultimately to a decreased renal blood flow and anuria. In severe shock, which can result from dehydration alone, the renal vascular bed is included in the generalized peripheral vasoconstriction. This may continue even when arterial blood pressure has risen to 100 mm. Hg. After a few hours the tubule cells of Henle's loop and of the distal tubules begin to degenerate. In the resulting nephrosis tubules lose selective reabsorptive powers, and all glomerular filtrate re-enters the circulation. This has been called "toxic nephritis",⁴⁵ but it is really the end result of uncorrected dehydration.⁴⁶

McCance⁴⁷ has studied the first stages of this process in human subjects with a low salt intake and placed under conditions where maximal sweating would occur.

Winkler⁴⁸ has studied the first stages of water deprivation in human subjects. At first fluid and electrolyte were lost proportionately. As more severe deprivation occurred the extracellular fluid volume contracted, and finally the intracellular water began to be mobilized. The organism at this time takes a compromise position between giving the kidneys enough water to excrete wastes and leaving enough water in the cell to maintain life.

Exchange of Sodium and Potassium.—Attention has recently been focussed on potassium shift, particularly in diabetic acidosis, infantile diarrhea and familial periodic paralysis.

Keys⁴⁹ noted that serum potassium levels dropped 20 per cent in patients undergoing insulin shock therapy. Potassium as well as inorganic phosphate is thought to be deposited with glycogen in both liver and muscle under these circumstances.⁵⁰ Following injections of intravenous glucose serum potassium levels also fall, and the inorganic phosphate levels fall even more sharply.⁴¹

Patients with diabetic acidosis, following apparently adequate insulin, glucose and fluid replacement therapy, have been found to have serum potassium levels of the order of 1 to 1.5 millicivalents per liter, whereas the normal range of serum potassium is between 3.5 to 5.5 millicivalents per liter.⁵²⁻⁵⁴ These patients show muscle weakness, gasping respirations, irregular pulse and a wide pulse pressure. Electrocardiographic

tracings show depressed S-T segments, frequent inversion of T waves and prolonged Q-T intervals.⁵⁵⁻⁵⁶ Administration of 10 to 30 gm. of potassium chloride orally relieves the clinical symptoms and reverses the electrocardiographic changes.⁵⁷⁻⁵⁹ Replacement of phosphate ion is also said to give better carbohydrate utilization, presumably because of more adequate phosphorylation.^{60, 61} The significance of low serum magnesium levels observed coincidentally is unknown.⁶²⁻⁶⁴

Gammon et al.⁶⁵ called attention to a group of patients with a *periodic paralysis*, familial in distribution, associated with a low serum potassium level. Others have confirmed the existence of this syndrome.⁶⁶⁻⁷⁰ The patients show electrocardiographic changes similar to those seen in diabetic acidosis associated with hypokalemia, and they regain muscle tone following administration of potassium. The paralysis seems to be associated with a redistribution of potassium within the organism rather than with potassium loss, according to Pudenz and his co-workers.⁷⁰ Danowski⁷¹ reports that potassium shifts into the cells with a resultant extracellular potassium content decrease. With the administration of potassium additional cation enters the cell before normal extracellular levels are restored.

In 1948 Darrow^{72, 73} reported a case of *infantile diarrhea* with the subsequent development of congenital alkalosis. The serum potassium level was 1.5 milliequivalents per liter. Serum sodium was quite low and serum chloride very low. As the result of dehydration intracellular potassium was thought to move out of the cell and to be excreted, while sodium entered the intracellular phase in increased quantity. When a solution of sodium and potassium chlorides was administered the infant retained large amounts of potassium and recovered. Darrow⁷⁴ recommends a solution containing 35 millimols of potassium per liter, 104 millimols of chloride and 53 millimols of lactate in treating infant diarrhea and resultant dehydration.⁷⁴ It has also been shown that calcium and phosphorus are retained in large amounts by the post-acidotic infant.⁷⁵ These infants show electrocardiographic alterations reversible upon administration of potassium that are similar to those observed in diabetic acidosis.⁷⁶

Identical findings are reported by Bellet et al.⁷⁷ in adults with vomiting after *intestinal obstruction*. These patients when deprived of potassium by excessive loss of intestinal secretions retain significant amounts of administered potassium.⁷⁸ This retention of potassium is thought to indicate a cellular deficit of this cation. Such deficits are frequently but not invariably associated with a low serum potassium concentration. It is an observed fact that the kidney in the normal as well as the depleted patient, under supposed conditions of maximal need for potassium conservation, has a limited minimal rate of excretion of this ion. The continued renal excretion of potassium is thus an important factor in producing the potassium-deficient state.

Prior to the correlation of serum potassium depression with a clinical syndrome, a number of investigators reported hypochloremic, alkalotic

states which were refractory to the administration of sodium chloride.⁷²⁻⁷⁴

The characteristic chemical changes observed are low serum potassium levels, low serum chloride levels and a high carbon dioxide combining power. The blood pH has also been found to be elevated. The mechanism of this imbalance is as yet not clearly understood. The loss of intracellular potassium in excess of that associated with protein catabolism is a general response to water depletion from any cause.⁸⁵ The kidney then removes this potassium from the serum.

Rats with experimental pyloric obstruction develop a chloride depletion followed by alkalosis and a decrease in serum and muscle potassium.⁸⁶ Darrow,⁸⁷ in studying the relation of serum bicarbonate concentration to muscle electrolyte composition, has found that the serum bicarbonate varies directly with the concentration of intracellular sodium and inversely with the concentration of muscle potassium.⁸⁷ He considers that this relationship may possibly be considered a biological equilibrium attained when renal adjustment is made in the presence of a sodium chloride or potassium deficit.

The work of Keys⁸⁸ (vide supra) concerning the fall of serum potassium levels following injection of insulin has been amplified by later work.⁸ Castledon⁸⁹ has noted that injection of insulin simultaneously with the ingestion of glucose produces a preliminary lowering of the serum potassium level. This effect is also produced by the injection of epinephrine. Castledon believes that not all of this effect is related to the deposition of potassium during glycogenolysis.

Larsen⁹⁰ has studied the action of epinephrine in more detail. He finds that immediately following injection of epinephrine the plasma potassium level rises, due to the freeing of potassium from the liver during glycogenolysis. This is followed very shortly by a drop in serum potassium to below normal pre-experimental levels, consequent upon potassium uptake by muscle and liver. This is not thought to be all secondary to insulin mobilization. The pH of the blood rises as the potassium content of the extracellular fluid falls.

Stickney⁹¹ has studied the epinephrine effect in several different species. In the frog, dog, sheep and goat the epinephrine causes a rise and then a rapid fall in serum potassium. Perfusion of the frog's hind limbs showed that potassium intake was independent of flow and that epinephrine had no demonstrable direct effect upon the muscle uptake of potassium.

It becomes apparent that sodium and potassium exchange is not a simple ion membrane permeability problem. Both sodium and potassium within the cell exist in part as bound, osmotically inactive substance.^{91a, 92} The varying concentration of sodium and potassium, as well as phosphate ions, within and without the cell, may be an expression of specific affinities of the definite colloids of each particular cell type for these ions, rather than an expression of membrane permeability.⁹³⁻⁹⁵

FLUID REPLACEMENT THERAPY

Fluid requirements for the uncomplicated surgical case, in the absence of abnormally large water and salt losses, can be met by the use of 5 per cent glucose in water. One must replace the insensible water loss, and furnish the amount of fluid that will be required to assure an adequate urinary output. This means that about 2.5 liters will suffice for the average adult. These patients will usually begin to maintain an adequate oral intake within twenty-four hours after operation.

Determination of Fluid and Electrolyte Values.—Management of the patients with large exchanges of fluid and electrolytes cannot be accomplished without an accurate record of intake and output. All fluid loss, i.e., vomitus, drainage, urine, should be measured. Changes in body weight from day to day give a reasonably accurate index of change in total body water.

Relative changes in plasma and blood volume can be determined with sufficient accuracy for clinical purposes using Evans' blue dye, T-1824.^{96, 97} It is important to use the three-sample technic, taking samples over a forty-five minute period, rather than the technic using one sample taken ten minutes after the injection of the dye. We believe the former technic is preferable since the dye mixing is often incomplete in ten minutes in patients with abnormal findings, and since the disappearance rate of the dye may vary with the individual and with the state of his circulation.

Relative shifts in extracellular fluid may be estimated, again with sufficient accuracy for clinical purposes, from the diffusion volume of some substance such as thiocyanate.⁹³

The introduction of the flame photometer has made possible the rapid, accurate determination of sodium and potassium in biological materials.⁹⁹⁻¹⁰¹ This permits determination of the important elements of fixed base rather than the computation of their approximate concentration from the chloride and carbon dioxide content of serum.

Replacement of Fluid and Electrolytes.—Knowing the volume of water lost by various routes and the concentration of electrolytes in these fluids, one is in a position to make a roughly quantitative replacement of the lost electrolyte solution. It must be emphasized that in using this method one is always one day behind; in a manner of speaking "one pays for yesterday today." This means that if the volume of drainage suddenly diminishes there is some danger of overcorrection. However, vigilance and the spacing of fluid intake will prevent gross error.

It is well to avoid formulas based on blood levels of electrolyte alone in determination of salt requirements, for electrolyte stores are badly depleted when the serum concentrations are still only moderately below normal levels.¹⁰² Methods based on urinary excretion of chloride or sodium alone are also unreliable. In patients with some renal injury, one may have on the one hand a failure of the kidney to excrete chloride, although blood levels are pathologically high, and conversely patients

with a salt-losing nephritis simulating excretion of excess salt,¹⁰⁷ or even adrenocortical insufficiency, may actually have impoverished electrolyte reserves.

In patients with marked dehydration it is well to avoid if possible the use of protein hydrolysates at first, or of oral protein intake, until hydration has been re-established. Pariera¹⁰³ has reported that the prevention of starvation and sparing of protein require not less than 200 to 350 gm. of glucose per twenty-four hours for the average adult. This would necessitate the use of 10 per cent glucose to avoid an excessive water load. Danowski¹⁰⁴ has studied the same problem in dogs fed a dry protein ration during dehydration. Winkler⁴⁸ in a study of fish and carbohydrate diet in the dehydrated man, cast away at sea, also found that carbohydrate decreased the negative nitrogen balance and ketosis, and produced a smaller urine volume with less severe dehydration. The water of oxidation of the carbohydrate was also available to alleviate dehydration to some degree. Lockhart¹⁰⁵ has calculated that 0.5 gm. of glucose per kilogram of body weight per hour is the maximum advisable administration rate. Above this rate glycosuria appears, and with higher concentration of glucose diuresis is increased.

Schemm¹¹³ has cautioned against too rigorous water restriction in

than edema or azotemia. Mokotoff¹¹² has shown that renal tubules reabsorb a mean of 13 millimols of sodium from every 100 ml. of glomeru-

constant, and that the decreased excretion of sodium in congestive failure is due to a decreased glomerular filtration rate in the presence of normal tubular reabsorption. Merrill¹¹⁴ has obtained additional evidence in favor of this explanation.

A word of caution might be inserted here concerning ways of limiting salt intake in cardiac patients. Two recent reports have indicated that the use of lithium chloride in dietary salt substitutes may be detrimental.

If the patient has a low plasma protein, this should be corrected by transfusion.^{117, 118} If there is reason to suspect a decreased blood volume preoperatively, as in cases of possible malignancy or cachexia, the volume should be determined, and a normal volume restored by transfusion if indicated. During extensive surgical procedures it is helpful to determine blood loss by some means, such as weighing dry sponges before and after use, and then to replace this loss while the patient is still on the operating table.¹¹⁹

One should not hesitate to give large amounts of salt solution where this is indicated, as in cases of severe dehydration or in cases with copious drainage.

Replacement of Potassium.—The rationale for potassium replacement is based on the fact that adult patients losing potassium through continued renal excretion, and through abnormal loss of gastrointestinal tract secretions, retain significant amounts of administered potassium.⁷⁷ When such loss is observed, with or without marked lowering of the serum potassium level, it appears rational to replace the potassium, if possible by the oral route. In any case where potassium is replaced, whether by oral or parenteral route, one must exercise due caution in giving potassium to patients with renal damage. The failing kidney does not consistently excrete excess potassium.^{120, 121} Under such circumstances excessively high serum potassium has been known to cause death, apparently by cardiac arrest in diastole, at serum potassium levels of about 10 milliequivalents per liter.^{122, 123}

SUMMARY

Fluid requirements for the uncomplicated surgical case, in the absence of abnormally large water and salt loss, can be met by the use of 5 per cent glucose in water. These patients can usually be depended upon to maintain themselves on oral intake after the first twenty-four hours following operation.

Management of cases involving large exchanges of fluid and electrolyte necessitates accurate recording of intake and output, the concentrations of the various ions in these drainages and a knowledge of the pathologic and physiologic exchanges of water and salts that can occur between cells, extracellular fluid and the blood stream.

In the treatment of such cases, with or without pre-existing dehydration, relatively large amounts of sodium, chloride and often potassium must be used.

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THE SURGICAL CLINICS OF NORTH AMERICA

PHILADELPHIA NUMBER

SYMPOSIUM ON RECENT ADVANCES IN SURGICAL PHYSIOLOGY

FOREWORD

The December 1946 number of the *Surgical Clinics of North America* contained a symposium on Surgical Physiology. That it proved useful can be attested by the many favorable comments which were made of it following publication and by the many requests which have been received that it be brought up to date. No attempt has been made to review every subject which was covered three years ago. The subjects in this issue are of a wider scope and the consulting editor is responsible for their selection.

Surgery has become more extensive in its scope and in the opportunities provided for recovery and for restoration to economic usefulness because of a wider knowledge of the pathologic physiology of disease. It is only by a wider dissemination of such knowledge that surgeons everywhere can benefit from the knowledge acquired by a few surgeons working in specialized fields.

The operation may always remain the most dramatic part of surgical therapy, but few would deny the fact that improvements in preoperative and postoperative care and a broader knowledge of the factors influencing disease, injury and repair are usually more important in reducing the morbidity and mortality of operations.

I. S. RAYDIN, M.D.
Consulting Editor

SURGICAL PHYSIOLOGY OF ACUTE HEAD TRAUMA

BARNES WOODHALL, M.D., F.A.C.S.*

Progress in the general problem of head injury has been achieved in two ways; first by a clearer understanding of the altered physiology of an acute head injury in various age groups; and second, by a meticulous delineation of the various traumatic syndromes whose fatal advance can be reversed by the application of proper therapeutic and diagnostic methods. The physiologist, under various titles, has gained an almost perfect appreciation of the diverse response of the human brain to trauma. This academic knowledge has been used to illuminate clinical practice to the benefit of the individual patient. Unfortunately, the reduction of mortality and morbidity entails more than the efforts of the specialist in this field alone. It depends upon the steady flow of pertinent information to all physicians who necessarily encounter head injuries as emergencies of practice and upon more attention to the barely touched field of public education in this aspect of accident control. The incidence of accidental injury continues to advance in the home, on highways and in industry, although little information is available concerning the place of head injury in the total problem.^{1, 2, 3, 4, 5} In industry, the National Safety Council has estimated that 7 per cent of the total number of compensated cases are head injuries and that these cases accounted for about 13 per cent of the total compensation.⁶

The immediate task within the scope of the neurosurgeon is to define (1) the contributions of physiology and allied sciences in this field, (2) the technic of emergency therapy and supportive therapy, (3) the means of making a precise diagnosis, and (4) the definition of traumatic lesions that should, if feasible, enter the domain of the trained neurosurgeon.

CLASSIFICATION OF ANATOMICAL PATTERNS OF INJURY

As the physician encounters a head injury patient, it is imperative that he already possess some concept of the potential anatomical patterns of injury that may involve the covering structures of the brain or the brain itself. Since infection has weighed so heavily in the past against recovery in head injuries and still may be a potent factor, the primary classification of importance is that of *open* or *closed* head injury. An open head injury may be defined as one in which brain tissue is exposed to the outside environment, and thus to infection, either through direct involvement of scalp, skull and meninges, or indirectly through fracture

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pita.

of air-containing sinuses that are continuous with cranial orifices, the nose, mouth and ear. A closed head injury is one in which this direct continuity of tissue injury is obviously, or can be proved to be non-existent.

Scalp.—Laceration, brush burns, contusions and hematomas of the scalp and areas of edema, hemorrhage or fluid formation must be related to this primary classification. Open wounds of the scalp must be related to the wounding mechanism that existed in any particular injury and must be considered open head injuries until disproved. Trivial wounds of the scalp may overlay massive brain damage in stab and missile injuries, for example. On the other hand, aspiration of scalp hematomas and collections of fluid are contraindicated for fear of compounding an existing closed head injury.

Skull.—Fractures of the skull have been classified according to their location, be it vault or base, for instance, according to their appearance in the skull roentgenograms, in terms of their involvement of special cranial structures or by the common terms of compound or simple skull fracture. Such a classification has a descriptive but limited importance. It must always be related to the physiological approach that the skull represents a defense mechanism against brain damage and that forces deforming the skull, and causing fracture, may likewise deform brain tissue.

The deformation of the skull subjected to blunt force has been demonstrated by several technics. Pudenz and Sheldon⁷ observed with the lucite calvarium and high speed cinematography that the skull was deformed locally by the blow but could not visualize contrecoup expansion. This was shown to exist by Gurdjian and Lissner using the strain gage—cathode ray oscilloscope technic.⁸ These same observers have demonstrated lines of skull deformation with the "stresscoat" technic following blunt force applied to various portions of the skull. The distribution of such deformation patterns in general paralleled fracture lines observed in clinical cases.⁹ The unyielding adult skull, when moving or freely suspended, directly transmits blunt force to the enclosed brain. When the skull is fixed, brain damage may be minimal with the major impact being absorbed by skull failure (fracture). The clinical counterparts of these physiological findings may be encountered in patients with severe brain damage without significant skull fracture and, on the other hand, in those with no change or little alteration in a normal state of consciousness but who show extensive skull fracture. Pudenz and Sheldon⁷ have shown that brain movement is minimized with skull fixation and this finding is in accord with earlier experimental^{10, 11} and clinical studies.^{12, 13} In sharply localized injuries by stab wounds or low power projectiles, skull fracture occurs at the narrow point of maximum force. In childhood, since the skull is relatively elastic, the impact of an accelerating or decelerating force may be dampened by the yielding skull, with the production of the typical linear fracture lines of head injury at this age and with relatively minor cerebral damage.



Fig. 575.—Traumatic encephalocele.



Fig. 576 —Linear fracture of skull in 3 year old child.

Other illustrations might be added to show the diversified changes that may occur with skull damage but they would but serve to emphasize



Fig. 577 —Localized depressed skull fracture in closed type of head injury



Fig. 578 —Fracture of frontal bone and cribriform plate with delayed cerebrospinal fluid rhinorrhea

further the fundamental concept that the skull fractures as a dampening mechanism against forces applied against it but all too frequently must transmit force to the underlying brain. The recognition of certain skull fractures aids in the diagnosis of specific clinical syndromes and since these will be referred to subsequently, a classification of injuries of the scalp and skull may be listed at this place.

CLASSIFICATION OF HEAD TRAUMA

Scalp: Laceration

Avulsion

Contusion (pseudo-depressed fracture)

Brush burn

Subgaleal hematoma

Subgaleal collections of cerebrospinal fluid (traumatic meningocele) (Fig. 575)

Localized edema or hemorrhage

Skull:

1. Compound or simple fractures

2. Linear, comminuted or depressed fractures (Figs 576 and 577)

3. Fracture involving base or vault

4. Fracture involving special structures including air-containing sinuses and major vessel channels (longitudinal sinus, lateral sinus or middle meningeal artery) (Fig. 578)

The Meninges.—In addition to actual laceration of the dura and pia arachnoid that may accompany an open head injury, certain anatomical relationships between major vessels and the meninges allow the potential development of massive hematomas both extradurally and in the latent subdural space. Extradural bleeding occurs in closed head injury from laceration of the middle meningeal artery and its adjacent meningeal veins. Since these dural vessels are closely adherent to the inner skull surface, or may actually penetrate the inner table of the skull, the deformation of the skull noted above may result in skull fracture across the adherent or contained blood channel, with subsequent hemorrhage. Dandy¹⁴ has reemphasized the early teachings of Percival Pott and Jacobson that skull deformation, proved by the physiological methods already quoted, may actually displace dura without evidence of skull fracture with the rapid development of a typical extradural hematoma (Fig. 579).

The second type of massive hematoma observed in clinical practice has its anatomical basis in the vascular arrangement of venous channels traversing the subdural space, in particular from the cortex to the longitudinal sinus. The physiological background for the development of this so-called "chronic subdural hematoma" necessitates further attention to studies devoted to the effect of force transmitted to the brain.

When subconcussive blows in the parietal and temporal areas of monkeys fitted with lucite calvarium were observed,⁷ brain movement was found to be more extensive and more complicated than in the frontal and occipital injuries. Cerebral rotation occurred in a horizontal arc

and, as the brain came to a state of rest, the decreasing oscillations were particularly prominent in the parietal lobes. During the phase of maximum cerebral rotation, there was considerable stretching of the surface

veins.

Volitional guide was greatest and this finding appears to be in entire agreement with the location of subdural hematomas as found in clinical practice.

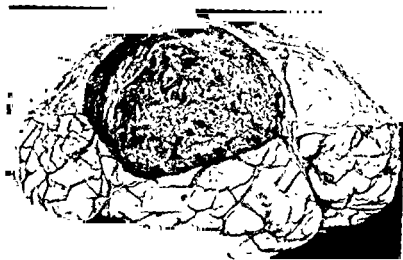


Fig. 579 —Extradural hematoma, right

An "acute subdural hematoma" may be found in head injuries in which laceration of the cerebral cortex allows concomitant arterial and venous bleeding through the lacerated pia arachnoid into the subdural space. In those relatively uncommon injuries in which the arachnoid is torn without injury to other integuments of the cranium, leakage of cerebrospinal fluid into the subdural space may become so marked that the resulting fluid mass gains the appellation of a "subdural hygroma."

The Brain.—Tissue damage to the brain following trauma may be classified for clinical purposes into that of concussion of the brain, laceration of the brain, subarachnoid hemorrhage, cerebral edema, intracerebral hematoma, intraventricular hemorrhage and such changes associated as well with the retention of foreign bodies and of atmospheric air. The mechanism of cerebral damage entails a further consideration of inflicting forces.

Cerebral Contusion.—Theories concerning the causation of focal and contrecoup damage to the brain originated, according to Pudenz and Sheldon, in the vibration theory formulated by the various members of the Paris Academy of Surgery in 1766. When the subsequent theories

are reviewed, it is clear that most writers have recognized the primary fact that the brain moves with relation to the skull. This matter was clarified by Holburn on purely physical principles.¹⁵ He stated that the prime requisite for contrecoup damage is that the head be set in rotation by the blow. This rotation, in various planes, is transmitted to the brain which glides in its dural compartments. In areas where the brain is confined by bony structures, in the frontal and middle fossae of the skull, shear strains occur which lacerate cerebral tissue and tear blood vessels. As noted above, this theory is strongly supported by Pudenz and Shel-



Fig. 580.—Cortical hematoma in hemisphere opposite to extradural hematoma

don's direct observation of brain movement when the freely suspended head is struck by subconcussive blows. Both the speculative theory and the confirming observations are in accord with the clinical distribution of cerebral lesions in fatal cases of head injury described by Vance,¹¹ LeCount and Apfelbach,¹³ by Courville¹⁶ and more recently by Botterell.¹⁷

The proven existence of skull deformation and transmitted gliding movements appear sufficient physiological explanation for cerebral contusion, including contrecoup injury, subarachnoid hemorrhage, the development of extradural and subdural hematoma, and in all probability, intracerebral hematoma (Figs. 580 and 581). It is also clear that

brain movement is markedly reduced when force is inflicted upon the

Further clarified the physiological

flattening of the brain against

id not cause visible



Fig. 581 —Extensive traumatic subarachnoid hemorrhage

rotation of the brain. By microsecond roentgenographic technics and by tissue studies, several observers^{18, 19, 20, 21} have agreed that the passage of a high velocity missile through tissue, including the brain, produces a large, rapidly expanding pulsating cavity. The pressure within this cavity produces a high radial velocity to surrounding tissues, and in the case of the brain, may be great enough to cause extensive comminution of the bones of the skull. The wound of exit, involved in the expanding pressure cone, is always greater than the wound of entry. If the brain is removed prior to wounding, the damage to the skull is localized and

relatively minor. In the intact head, the increased pressure is dispersed throughout the closed system of the brain, a form of compression concussion, and may be manifested by a fatal response of the medullary centers. Matson²² has described the clinical counterparts of these physiological studies in his monograph on war missile injuries of the head. Of particular importance in the low-velocity missile injuries of civilian life is the recognition and treatment of hematomas that may appear at the point the penetrating missile comes to rest against the inner surface of the skull opposite the wound of entry.

Concussion of the Brain.—The physiology of concussion has gradually accumulated considerable data with emphasis upon the concept that concussion is due to a mechanical effect upon the nerve cell. Denny-Brown and Russell¹⁰ have defined concussion as "an immediate traumatic paralysis of reflex function" and have shown that acceleration of the freely suspended head from zero to a speed of 28.4 ft./per second produced so-called acceleration concussion. Since this form of concussion is dependent on the rate of increase in velocity, it is clinically evident that any factor that dampens the blow will materially protect the brain.²³ Continuing an experimental analysis of concussion, Walker, Kollros and Case²⁴ concluded that the concussion syndrome should be considered excitatory rather than paralytic and postulated that the paralytic phase of concussion was merely the normal physiological sequel of the primary intense stimulation period (extinction). They demonstrated a sudden increase in pressure at the site of impact with pressure waves being transmitted throughout the cranial cavity and postulated axonal discharges through this mechanical force causing polarized cell membrane breakdown.

Although the exact mechanism at play in the brain at the moment of impact is still open to controversy, there is unequivocal evidence that definite histopathological changes exist in the brain of concussed animals. Windle and his group^{25,26,27} have demonstrated chromatolytic changes, in rats, guinea pigs and monkeys, in the cells of the motor cortex, large neurons of the tegmentum, lateral vestibular nuclei and in the reticular formation of the medulla oblongata. That the end products of the chromatolysis of nerve cells may appear in the spinal fluid has been shown by Spiegel-Adolf, Henny, Wycis and Spiegel. In concussed animals and humans, these investigators found an absorption band in ultraviolet light at a peak of about 2650 Å, characteristic of such nucleic bases as purin and pyrimidin.²⁸

Cerebral Edema.—The concept that cerebral edema is common in head trauma has profoundly influenced therapy, particularly that of closed head injuries. The use of passive dehydration by limitation of fluid intake, spinal fluid drainage and the administration of dehydrating agents such as 50 per cent solutions of glucose and sucrose, and plasma, have been advocated. When available clinical and experimental studies are reviewed, there appears to be scant evidence for this primary conception.

Connors and Wright²⁹ and Vance³² could not find instances of gen-

eralized cerebral edema that could be held responsible for patient death. The experimental work of Shapiro and Jackson³⁰ noted no evidence of true cerebral edema after trauma. Pilcher^{31, 32} similarly could find no evidence that marked cerebral edema occurred after experimental head trauma. White, Brooks, Goldthwait and Adams,³³ on the other hand, subsequently demonstrated a 5.5 per cent increase in brain volume after experimental head trauma. This experimentally induced brain swelling varied with the degree of concussion, appeared at fifteen minutes after injury, reached its greatest extent between five and twenty-four hours, and subsided after three days. These investigations emphasized, in addition to this change, the great influence of localized brain contusion,

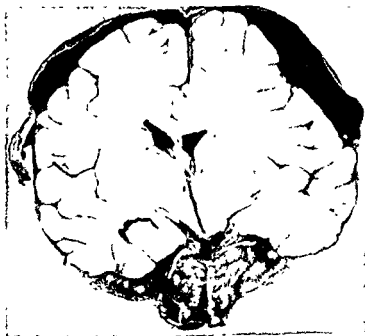


Fig. 582 —Bilateral subdural hematoma with early bilateral herniation of uncus

anoxia from an obstructed airway, failure of the respiratory center and *respiratory depressant drugs* upon the production of clinical significant brain edema. Greenfield³⁴ tends to disclaim the importance of edema in head injuries, stating that it occurs only with thrombosis of cerebral vessels and in the local area of brain contusion. Evans and Scheinker

...hanges that appear in the brain
ends the warning
the diagnosis of
cerebral edema is used as a cloak to conceal our ignorance of the cause of certain cerebral states".³⁵

Changes in the Brain Responsible for Death—The changes in the brain responsible for death or the agonal state are fairly well appreciated

They may be grouped into primary, secondary and complicating factors. Primary lethal damage has already been described in terms of subarachnoid, intracerebral and intraventricular hemorrhage, resulting from laceration of the brain and its vascular supply. In 61 autopsies from patients succumbing immediately after injury, Gurdjian, Webster, and Arnkoff²⁷ described in nineteen cases punctate hemorrhages in the medulla and pons with little or no other associated intracranial lesions to explain the death. In a study of the acute physiologic responses to



Fig. 583.—Bifrontal laceration of orbital surfaces of both frontal lobes. Note small cerebellar pressure cone.

trauma, Gurdjian and Webster²⁸ were able to duplicate these clinical findings in the experimental animal. The extent and degree of this primary injury determines the potential result with or without treatment. Secondary and progressive factors are those related to the development of massive hematomas and to cerebral edema and tissue infarction secondary to vascular damage. The normal physiology of the adult brain is largely dependent upon the concept of the skull as a "closed box," incapable of significant expansion.²⁹ When intracranial pressure rises as a result of these secondary, and untreated factors, brain

tissue may be forced beneath the falx, through the hiatus of the tentorium and into the foramen magnum. Cerebellar herniation, the cerebellar pressure cone of Cushing, is infrequently seen in head trauma since the cerebral hemispheres usually sustain the blunt of the injury. Herniation of the uncus of the temporal lobe through the opening of the tentorium against the midbrain was described by Kern³⁹ in 1906. It dilates



Fig. 584 —Base view of unilateral herniation of uncus, left, secondary to laceration of left temporal lobe.

It may cause false localizing hemiplegia by pressure of the opposite peduncle against the sharp edge of the tentorium.⁴² It may so kink the posterior cerebral artery that thrombosis of the vessel and occipital lobe infarction may ensue.⁴⁰ Finally, unless relieved, it may progress to such a degree that midbrain compression is signified by decerebrate rigidity, the development of venous hemorrhage in the pons and by death. (See Figs 582 to 586.)

The complicating factors have to do with the ingress of matter foreign to the brain, and include bacteria and atmospheric air. Infection enters through compound fractures, including the fractures through the anterior sinuses and through the mastoid with the clinical appearance of spinal



Fig. 555.—Unilateral uncus herniation, right, illustrating compression of pons

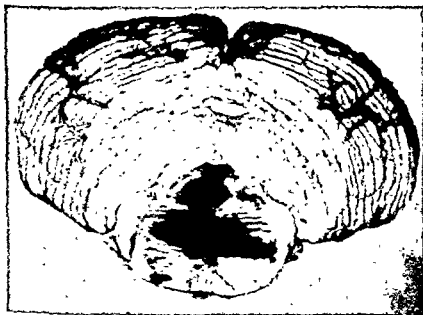


Fig. 556.—Terminal venous hemorrhages in pons in fatal head injury.

fluid rhinorrhea and otorrhea. Pneumocephalus may occur when atmospheric air enters the meninges, brain or ventricular system through similar fractures.⁴²

EMERGENCY THERAPY

Equipped with some insight into the mechanism of injury and its potential anatomical patterns, the surgeon will encounter patients with head trauma, who at their best appear to be formidable problems indeed. Few head injuries with the exception of a rapidly deteriorating case of extradural hematoma qualify for the cognomen of a true surgical emergency and time is usually available for cogitation and for a step-by-step regimen of handling. The first principle of this sometimes variable routine has to do with *resuscitation* or an evaluation and treatment of the



Fig 587 —Compound fracture of occiput from mule kick. Patient resuscitated and multiple injuries treated prior to definitive operative treatment

patient in terms of his general body reaction to the local head injury. This term in practice covers several distinct operations. They are in order.

The Immediate Treatment of the Local Wound.—In patients with *open* head injury at the time of admission, the hair is clipped away from the edges of the wound and a firm pressure dressing is applied. Such a dressing will control hemorrhage in most instances. Occasionally a hemostat may be needed to control bleeding from a large scalp vessel, such as the superficial temporal artery. Foreign bodies, such as rock fragments, knives, automobile door handles and the like, protruding from the wound, are left in place since their removal may precipitate further bleeding that is difficult to control at this stage of treatment.

The Evaluation and Treatment of Shock.—Patients bleed copiously from scalp wounds, and with the general impact of the inflicting force, may show profound shock. They seem to hold themselves together, as it were, until they reach a treatment center and then begin to deteriorate. Intravenous 5 per cent glucose in normal saline solution should be

started in the accident room and preparations made for the use of whole blood. One must remember that patients with these injuries are facing a potential major operative procedure in which less of blood will be an inevitable accompaniment of repair.

The Assurance of an Open Airway.—Major head wounds may occur at any time with or without loss of consciousness and patients may be poorly prepared to control vomitus from recently ingested food, blood from nasal or mouth hemorrhage and secretions from the upper respiratory tract. Aspiration of the airway is essential to prevent the ingress of foreign material and to obviate anoxemia which will in turn encourage intracranial hemorrhage and a rise in intracranial pressure. The modern anesthetist has now become the fifth wheel of the appplecart of neurosurgery and on many occasions indeed has prevented that appplecart from overturning. In extreme cases of respiratory embarrassment, a formal tracheotomy is indicated and may be lifesaving. Ether anesthesia by means of an endotracheal tube appears to be the anesthesia of choice in major compound injuries. This phase of resuscitation concerned with the assurance of an open airway, the prevention of aspiration of foreign bodies, of acute atelectasis and of actual self-drowning by blood and secretion flows naturally into the phase of endotracheal anesthesia free of such complications during the period of operative repair.

Serious concomitant injuries to the chest, abdomen, spine and extremities may be associated with head injuries particularly when the inflicting forces are those present in vehicular accidents. Even relatively minor head injuries may forcibly flex the cervical spine and such spine injuries may be unrecognized during the acute episode.⁴⁴

At this time, patients with closed or open skull fractures should be transported to a specialized treatment center.

THE NEUROLOGIC AND ROENTGENOGRAPHIC DIAGNOSIS

All types of head trauma are dynamic injuries, progressing favorably, maintaining a variable clinical position comparable to the admission status or deteriorating. The neurologic examination, which includes an estimation of the degree of consciousness and a record of temperature, pulse, respiration and blood pressure, is carried out at admission as a baseline observation and must be repeated at frequent intervals. Cushing's original physiological studies upon the human have been confirmed repeatedly in clinical practice.⁴⁵ A record of temperature, pulse rate, respiratory rate and blood pressure must be made at fifteen to thirty minute intervals. A rise in temperature, the development of bradycardia, an irregular respiratory rate and an elevation of the blood pressure serve as objective indices of increasing intracranial pressure or a failure in normal cerebral physiology.

The *state of consciousness* represents the most delicate index of the patient's progress following head trauma. Some mention has already

been made of the excitatory—paralytic phenomena current at the moment of wounding that represent the syndrome of concussion. The depth and length of initial loss of consciousness appears dependent upon the gravity of the initial injury. Loss of consciousness due to a slow increase in intracranial pressure has not been well explained on physiological grounds although Dandy⁴⁶ has published a provocative paper on this matter implicating the basal ganglion and in particular the corpus striatum. The state of consciousness, in terms of coma, semicoma and confusion should likewise be recorded at periodic intervals with as much pertinent explanatory data as is available.

With the exception of the examination of the injured head, the neurological examination in unconscious patients must necessarily be a limited one and largely restricted to objective findings. A continued observation of *third nerve function* in terms of anisocoria and pupillary reaction to light stimulus is mandatory. A dilated pupil with impairment of the light reflex is indicative of one of at least three pathologic lesions: (1) extradural hematoma or other unilateral hematomas with herniation of the temporal uncus through the tentorium; (2) rupture of the extrapontine nerve segment, and (3) injury of the nerve segment at the superior orbital fissure or within the orbit. Recent clinicopathological studies have suggested a forebrain origin for some instances of pupillary dilation in head injuries in which the light reflex is preserved.⁴⁷ Bilateral constricted pupils and bilateral dilated and fixed pupils are indicative of an agonal stage of brain injury and appear to be part of total cerebral paralysis. Papilledema may appear two to three days after the acute trauma if intracranial pressure by virtue of a progressive lesion becomes apparent.

Facial grimaces or comparative extremity movement may furnish evidence of a hemiparesis. In semicomatose or comatose patients, this motor response can be elicited by noxious stimuli, such as that furnished by supraorbital pressure. Muscle-tendon reflex changes and the presence or absence of the Babinski toe extensor sign may aid in localizing a cerebral injury. Such a neurological survey, limited as it may be, must be repeated at frequent intervals during the initial phase of injury.

Roentgenograms of the skull in acute trauma are mandatory in all open head injuries. They will show the position and number of depressed skull fragments, involvement of air-containing structures of the skull and the presence and location of foreign bodies. In closed head injuries, they may demonstrate fractures crossing the middle meningeal artery, a pineal shift if the structure is calcified and aid in proving the fact through the presence of a fracture, that head trauma has been sustained. Roentgenograms in head trauma, taken at some period during hospitalization, possess considerable appeal in medicolegal disputes. The matter of skull roentgenograms should not be forced in very restless patients or when there appears some contraindication to movement of the patient. If clear plates can be secured with reasonable patient safety, they are always of some diagnostic aid. They must be taken in stereoscopic projection.

THE DIAGNOSIS AND THERAPY OF CLOSED HEAD INJURIES

Following the resuscitation and the neurologic—radiologic survey of any individual patient, the physician must make a vital decision in terms of treatment, and this has largely to do with the question of operative intervention. In closed head injuries, the problem has been reduced to the simple statement that all closed head injuries that are deteriorating have an operative hematoma until disproved by exploratory trephine. Such hematomas may occur as a sequel of mild and severe initial injuries.

Extradural Hematomas.—The anatomical background of this grave hemorrhage has already been described. Because of diagnostic failure and operative delay and rarely because of lethal brain injury, the mortality of this lesion attains that of 50 per cent. In the classical syndrome, the patient is dazed or made momentarily unconscious by usually a mild head blow. The syndrome is fairly common among vigorous children who injure themselves at play, for instance. The so-called "lucid" interval follows the initial concussion or neuronal injury while the hematoma develops. A secondary loss of consciousness then develops that may be preceded by vertigo, nausea and vomiting and head pain. Localizing evidence of brain compression will next be manifested by contralateral hemiparesis, hyperactive muscle reflexes and by pathological pyramidal tract reflexes. As the developing mass causes uncal herniation, a homolateral dilated pupil results from third nerve paresis. With greater pressure, bilateral muscle rigidity, false localizing signs and decerebrate rigidity presage irreparable midbrain compression.^{48, 49} Since the time of increasing intracranial pressure often coincides with the usual retiring time for young children, these lesions are responsible for many unrecognized deaths in the 5 to 15 year old age group. The symptoms of an elevated degree of intracranial pressure must be explained to responsible relatives of all patients with closed head injuries. The classical syndrome may often be masked by concomitant brain damage or by acute alcoholism.

Acute Subdural and Intracranial Hematoma.—These lesions are formed in gravely wounded patients as the sequelae of cerebral laceration. They may be suspected in patients whose state of consciousness deepens or in whom a progressive neurologic dysfunction can be demonstrated. Rarely, an isolated intracerebral hematoma will follow head injuries of less magnitude.

The treatment of such hematomas, and their diagnosis in suspected cases, demands exploratory trephine and appropriate technical means of removal and belong in the domain of the trained neurosurgeon.

Chronic Subdural Hematoma.—Although acute and chronic forms of subdural hematoma are recognized, it has already been indicated that the pathological basis for each variety is quite different. The chronic form fills the latent subdural space as the result of bleeding from a transcortical vein and necessarily the mass develops but slowly (Fig. 582). Although it is the result of an acute, and often mild head trauma, its

clinical course is characteristically slow. Since the causal injury may have been so inconsequential that it is forgotten, the traumatic lesion is frequently confused with that of a brain tumor. The presenting symptoms are those of headache, nausea, vomiting, mental confusion and often those of convulsions and motor weakness. There may be a history indicating failure of full recovery from a minor head injury with a terminal sequence of signs and symptoms of increased intracranial pressure. Dandy¹⁴ has suggested that the blood mass does not increase beyond a certain size from primary bleeding and that the clinical picture is subsequently initiated by an irritative cerebral edema. Gardner²⁰ has proved



Fig. 588 —Chronic subdural hematoma in infant. Inner membrane over cortex—outer membrane held in tissue forceps

with human specimens that the thin inner membrane may act as a dialyzing membrane and postulates an increase in mass by transfer of fluid from the subarachnoid space into the increased protein substance of the hematoma. In the adult, this is another instance of a hematoma that must be disclosed by exploratory trephine.

Chronic subdural hematoma, however, is a frequent lesion of infancy.²¹ There is no exact clinical picture but convulsions, vomiting, irritability, irregular temperature swings associated with an accelerated head growth, muscle hypertonicity and hyperactive muscle reflexes should lead to early investigation. The diagnosis is readily

established by puncture and aspiration of the subdural space through the lateral angle of the anterior fontanel and can be made only by this procedure (Fig. 538).

Depressed Fracture of the Skull.—The problem of elevating depressed fractures of the skull in closed head injuries may be considered as an elective rather than an emergency procedure, unless the depression is of such a magnitude that intracranial pressure is elevated or serious neurological dysfunction exists. The small indented depressions of infancy often are corrected with normal skull-brain growth.

The Supportive Therapy of Diffuse Neuronal Injury.—As the attending physician observes a patient for the operative lesions of a closed head injury described above, and even when these are diagnosed and treated, he is engaged in a series of measures designed to support the physiology of an unconscious patient. The therapy of diffuse head injury has aroused much controversy, centering largely around the use of lumbar puncture and the use of dehydrating solutions.

The diagnostic and therapeutic values of *lumbar puncture* seem overrated. There is some doubt that accurate measurements of intracranial pressure can be made in restless patients and even in cooperative individuals, there is some evidence that an accurate index of intracranial pressure cannot be obtained by spinal subarachnoid puncture.⁵³ Spinal puncture will show the presence of subarachnoid hemorrhage but Sprong⁵⁴ has shown that such bleeding cannot be reduced by spinal fluid drainage and Meredith supports this finding.⁵⁵ Clinical experience has shown in the subarachnoid hemorrhage of congenital cerebral aneurysm that spinal fluid drainage may precipitate fresh bleeding. This danger and that of increasing an early uncal herniation appear to be valid ones. In acute lesions, spinal puncture is valuable in terms of differential diagnosis; spinal puncture and drainage of small amounts of fluid appear worthwhile in patients exhibiting headache during the convalescent period.

Intravenous hypertonic solutions have been used to reduce intracranial pressure resulting from the assumed presence of cerebral edema in head injury. Russell⁵⁶ was unable to show consistent reduction of intracranial pressure with hypertonic sucrose solutions and suggested that such solutions reduced the fluid content of normal brain and not of areas of cerebral edema. Browder⁵⁸ has warned against the use of hypertonic solutions. On the other hand, Shenkins and his co-workers⁵⁷ have demonstrated an improvement in cerebral circulation following the reduction of intracranial pressure by dehydrating agents. The use of passive dehydration by withholding fluid seems likewise based upon physiological reasoning that cannot be substantiated.

The *control of convulsions and restlessness* secondary to acute head trauma are everyday clinical problems. An acute convulsive state, at times resembling status epilepticus, may follow within minutes after injury and this manifestation of cortical injury is particularly noted in children. Localized, and occasionally, generalized seizures occur as part

of the syndrome of extradural hematoma and anti-convulsant therapy must be predicated on exclusion of this diagnosis. In children, subcutaneous administration of sodium phenobarbital in 30 to 60 mg. doses is advisable. In young adults, the slow administration of sodium amytal 0.1 gm. intravenously will suffice to control such seizures.

repeated doses, is often sufficient to control extreme degrees of hyperactivity. Temperature levels over 104°F. representing cerebral hyperthermia must be controlled by tepid water sponge baths or in extreme cases by iced alcohol towels.

Clinical experience has shown that the well-being of patients with diffuse brain damage depends more upon general supportive measures than upon reduction in intracranial pressure. White and his group⁵¹ have demonstrated an increase in brain volume with anoxia and cerebral congestion with hypercapnia. The resuscitation measures earlier described will insure a clear airway and the introduction of oxygen by any technic available will answer the increased need for oxygen demonstrated by the traumatized brain.

Full hydration and adequate nutrition must be maintained. An adult should receive 3000 cc. of fluid every twenty-four hours in three divided intravenous administrations and in excessively warm weather or in very restless patients, an additional 1000 cc. of fluid is indicated. A five per cent solution of dextrose in physiological saline solution and in distilled water in equal parts is desirable. At the end of three days, nutritional requirements should be met by intermittent nasal feedings of the following formulae.

	Food	Weight, gm	Cal
1 cal /cc.	Whole milk	600	414
	Skim milk powder	60	215
	Eggs, 4	200	316
	Tomato juice	200	46
	Total, 1000 cc		991
2 cal /cc.	Whole milk	200	138
	Skim milk powder	75	269
	Eggs, 4	200	316
	Tomato juice	200	46
	Sugar	120	478
	Cream (20%)	400	832
	Total, 1000 cc		2079
<hr/>			
(Low Fat)	Skim milk	800	280
	Tomato juice.	200	46
	Skim milk powder	200	715
	Total, 1000 cc.		1041

Oral hygiene must be maintained. If urinary control is lost, soiling may be controlled by an open condom drainage system or by an indwelling catheter. Comatose patients must be turned at two hour intervals and their airways continuously cleared to prevent anoxia and aspiration. Prophylactic penicillin therapy is sometimes indicated to prevent respiratory infection or parotitis.

In closing this discussion of closed head injuries, it is well to mention three rare varieties of injury, that related to thrombosis of major vessels,^{59, 60} that related to blast^{61, 62} and that related to the passage of electricity.⁶³

THE DIAGNOSIS AND THERAPY OF OPEN HEAD INJURIES

All that has been written concerning resuscitation, emergency therapy and the *neurologic and radiologic diagnosis applies even more forcibly* to patients with open or compound head injuries. Shock may be more profound due to blood loss and in open frontal-facial wounds in particular, the maintenance of an open airway may present difficulties that can be answered only by a tracheotomy.

Examination of the local wound by means of a gloved finger or by means of an instrument should be held to a minimum. Injury to the meninges or to brain tissue may be recognized by drainage of subarachnoid fluid or by the expulsion of traumatized brain fragments from the wound. The appearance of subarachnoid fluid from the nose or ear is pathognomonic of a special type of open head injury through the frontal sinus, the cribriform plate and the mastoid. The definite diagnosis of an open head injury and its extent if it exists can often be determined only at operation. Scalp laceration should be treated therefore with respect.

Anesthesia and Definitive Repair.—In major injuries, as a general rule, endotracheal ether anesthesia is the method of choice. In relatively mild injuries in conscious, well-integrated adult patients, local anesthesia may be used. The time of operative repair depends upon the results of resuscitation, if this has been deemed necessary, and to a lesser extent, upon the existence of severe, concomitant body injury. There should be no unseemly rush to the operating room—on the other hand, little is gained in severely injured patients after the first few hours of supportive therapy. The average time for the start of definitive repair will be found in the time range of 90 to 120 minutes after admission in uncomplicated cases. Definitive repair of the compound head wound (Fig. 589) should be and can be deferred until an intra-abdominal hemorrhage is controlled, a perforating chest wound closed or a fractured femur reduced and the like.

The operative repair must be considered as a single, all-inclusive removal (*débridement*) of all damaged tissue followed by such repair measures that will insure the reduction of an open or compound head injury into a simple, undrained closed head injury. This implies essentially the removal of necrotic scalp edges, free bone fragments, foreign bodies, blood clot and damaged brain followed by fluid-tight closure of dura and scalp without drainage.

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SURGICAL PHYSIOLOGY OF THE THYROID

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The purpose of this paper is to present a succinct review of thyroid physiology, stressing those aspects of the subject which should be known by the surgeon undertaking the management of patients with thyroid disease. The last decade has witnessed the discovery of a number of new tools for the investigation of thyroid activity, outstanding among these being thiouracil and radioactive iodine. As a result, our knowledge of normal and pathological thyroid function presents an ever widening horizon, so that a review of this nature cannot hope to be complete.

NORMAL PHYSIOLOGY

The comparative anatomy and physiology,¹ of the thyroid gland shows that its functions in all vertebrates are essentially the same. It is unique in that it is the only endocrine gland in the body which secretes a hormone, stores it outside the cells, and releases it into the circulation as required.² The secretory unit of the gland is the follicle, the cells of which manufacture the hormone thyroxine³ and store it within the lumen of the follicle as a protein bound substance, thyroglobulin. An average follicle has a diameter of approximately 300 microns,⁴ but there is a wide variation in the normal, the epithelium is one cell deep and these acinar cells are roughly as broad as they are tall; they show characteristic deviations from this pattern with changes in their secretory activity. When the gland is in a resting phase, these cells become flattened, whereas during increased secretory activity they become tall and Rawson⁵ has used the measurement of mean acinar cell height as an indication of thyroid activity. The homogeneous, eosinophilic substance which fills the follicle is usually called colloid. It has a protein structure,⁶ contains iodine and is probably stored thyroglobulin. Vacuoles may be seen in the colloid, especially in thyrotoxicosis, but are probably artifacts due to histological methods.⁷ They serve however, as a moderately reliable index of increased activity. The manufacture of colloid by the acinar cells was first recorded as long ago as 1892 and recently it has been well demonstrated by De Robertis⁸ using a freezing-drying technic. He showed that the thyroid cells secreted colloid, droplets of which could be seen traveling towards the lumen of the follicle. Since the thyroglobulin molecule

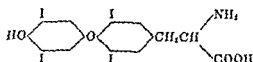
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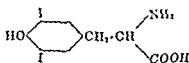
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was too large to permeate the cell membrane he explained this as due to the action of a proteolytic enzyme which split down the larger molecule into thyroxine-containing peptones or polypeptides. De Robertis^{9, 10} was able to demonstrate the presence of such proteases in thyroid tissue.

Kendall¹¹ was the first to extract a pure crystalline hormone from the thyroid and to this he gave the name "thyroxine." Subsequently Harington¹² succeeded in synthesizing this substance and showed it to have the chemical formula:



He postulated that it was produced in the gland by the interaction of 2 molecules of diiodotyrosine which has the formula:



Thus it is seen that the raw materials for the manufacture of the thyroid secretion are the amino acid tyrosine and iodine which inter-react in the thyroid cells with the eventual production of thyroglobulin to be stored within the follicle. This property of iodinating the protein molecule is by no means a reaction exclusively mediated by the thyroid. Abelson¹³ discovered in 1934 that he could iodinate proteins which on injection into rats produced exactly the same symptoms as an injection of thyroxine. Subsequently Lerman and Salter¹⁴ produced complete substitutes for thyroxine using in vitro preparations of serum albumin and iodine. During the recent war iodinated casein was developed on a commercial scale in England for the stimulation of milk production in cows.¹⁵

END ORGAN EFFECT

The actions of the thyroid hormone on the various tissues of the body are extremely diverse, but it will serve our purpose here to consider them under two main headings: (1) the action of thyroxine on general metabolism and (2) the action of thyroxine on the metabolism of certain specialized tissues.

Action of Thyroxine on General Metabolism.—The effect of thyroxine on cellular metabolism can be compared to a draught on a fire. The result in both cases is an increased consumption of oxygen with the production of heat. The hormone resembles in many ways an enzyme¹⁶ or catalytic agent, but so far we have no idea of the actual mechanism by which it works although we have many methods of measuring its effect. The most practicable of these is the basal metabolic rate (B.M.R.) introduced by determining the oxygen consumed by the subject under standard conditions.

resting conditions. In order to compare the B.M.R. of different persons it is necessary to express the results in terms of surface area of the individual and there are many tables which provide this information when the weight and height of the patient are known. These figures are usually recorded as a percentage greater or less than the average found in normal individuals.

Action of Thyroxine on the Metabolism of Certain Specialized Tissues.

—*Growth.*—Thyroxine is necessary for proper growth of the individual and tissue differentiation. Absence leads to cretinism, and Hertz¹⁹ showed that thyrotoxicosis in children was accompanied by an acceleration of normal growth.

Protein Metabolism.—This is affected by the thyroid and in myxedema a large amount of extra protein is stored in the body.²⁰

Water Balance.—This comes under the control of thyroxine, the giving of thyroid to a patient always inducing a diuresis.

Carbohydrate.—There is a profound upset of carbohydrate metabolism accompanying overactivity of the thyroid gland. Glycosuria is often discovered in case of thyrotoxicosis, it is not due to a lack of insulin, nor to a lowered renal threshold for glucose, nor is the fasting blood sugar level raised. The glycosuria is produced by an alteration in the glucose tolerance. If a thyrotoxic individual be given 100 gm. of glucose his blood sugar will rise to a higher peak than seen in a normal person.²¹

In hyperthyroid animals it has been shown that the liver has a sub-normal store of glycogen and even the administration of glucose will not restore liver glycogen to the average normal figure; similarly the administration of thyroxine depletes the liver of glycogen.²²

If a patient with thyrotoxicosis be given galactose by mouth and the level of the substance be determined at intervals in the blood, it will be found to reach a higher concentration than in a normal individual and at a greater speed. This result was attributed to a faster absorption of the galactose from the intestine than in hyperthyroidism.²³ Doubt has been cast on the validity of the test by Moseley and Chornock,²⁴ who intubated the intestine in normal and thyrotoxic subjects and showed that the galactose was not absorbed faster in the latter. Moreover they found that the blood level of galactose did not bear a direct relationship to the absorption from the bowel and could be depressed by the previous ingestion of glucose.

Fat Metabolism and Cholesterol.—The thyroid undoubtedly affects the storage and mobilization of the body's lipoids. The blood cholesterol being significantly lowered in hyperthyroidism and elevated in myxedema. Since there is a degree of correlation between the level of cholesterol in the blood and the basal metabolic rate,²⁵ blood cholesterol determinations have been used in the diagnosis of thyroid disease, but are not very reliable since malnutrition lowers the blood cholesterol level independently of thyroid activity. It seems most probable that thyroxine takes effect by mobilizing cholesterol into or out of the blood stream and not by altering cholesterol metabolism.²⁶

Central Nervous System.—Hypothyroidism is accompanied by a slowing of the individual's reaction time and cerebration. Conversely,

Exophthalmos.—Thyrotoxicosis is often accompanied by some protrusion of the eyeballs and retraction of the upper lids. Means²⁷ has drawn attention to those patients, usually middle aged males, who show minimal signs of Graves' disease but have ingravescent exophthalmos. Rundl and Wilson,²⁸ dissecting exophthalmos orbits postmortem, found an increase in fat, especially that infiltrating the ocular muscles. Experimentally, Dobyns²⁹ produced exophthalmos in guinea pigs by injections of thyrotropic hormone, there was marked edema of the orbital fat and muscles with lymphatic infiltration. An enormous literature has appeared on this subject and references to it may be found in Dobyns^{23, 30, 31} and Mulvany's³² papers. Lid retraction disappears when the thyrotoxicosis is controlled but the relationship of thyroid stimulating hormone (T.S.H.) to exophthalmos in man is, however, still obscure.

Skeletal Muscle and Creatine Excretion.—With hypersecretion of the thyroid there is always some degree of myasthenia, which in severe cases may lead to marked muscle wasting with a concomitant creatinuria. The normal adult male does not excrete creatine in the urine while the female may excrete small quantities periodically and large amounts in the puerperium. It was first shown by Shaffer in 1908³³ that patients with thyrotoxicosis excrete large amounts of creatine in the urine with an accompanying reduction in the output of creatinine. The degree of creatinuria offers a fair indication of the severity of the thyrotoxicosis, but it is not pathognomonic of the disease, only indicating the extent of the accompanying myopathy,³⁴ since many diseases with muscle dystrophy exhibit creatinuria. The determination of urinary creatine is a simple laboratory test and it has been employed as a diagnostic measure in doubtful cases of thyrotoxicosis.

Cardiovascular System.—Leblond³⁵ has shown that thyroxine has a direct effect in stimulating the heart's action quite apart from the indirect demands made through increased metabolism. It would thus appear that while the tissues require more oxygen in thyrotoxicosis, the heart is stimulated to provide them with more blood to meet this demand.

Other Endocrines.—The integration of the thyroid gland with the other endocrines is complex in the extreme, but two facts stand out. The injection of thyroxine inhibits the thyroid gland. Thyroxine appears to inhibit the secretion of thyrotropic hormone by the anterior pituitary. The first of these effects is not entirely dependent on the second since it has been shown that injection of thyroxine still inhibits thyroid activity in hypophysectomized animals.³⁶

The secretion of the thyroid hormone is subject to many fluctuations

in the normal individual and these are due to three main groups of causes. *First*, physiological variations in the other endocrine organs, especially the pituitary, produce changes in thyroid activity, e.g., minor alterations accompany each menstrual period, and pregnancy may lead to thyroid enlargement. *Second*, exposure to cold initiates a marked outpouring of thyroxine thus increasing metabolism and helping to maintain the body's temperature. Conversely in hot climates there is some suppression of thyroid activity. *Third*, the thyroid gland has a very plentiful supply of fibres from the cervical sympathetic nerves. Stimulation of these does not show increased glandular activity, but after sympathectomy in the experimental animal there is a fall in the B.M.R.,³⁷ and on exposure to cold there is a greater heat production than in a control animal. This suggests that the cervical sympathetic may have an inhibitory action on thyroid activity. On the other hand, Cannon³⁸ showed that cats developed exophthalmos goiter after anastomosis of the phrenic nerve to the cervical sympathetic chain. This was strong evidence that continued stimulation of the sympathetic led to oversecretion by the gland but in 1940 Friedgood and Cannon³⁹ showed that this stimulation of the thyroid had been routed through the anterior pituitary.

TOOLS FOR MEASUREMENT OF THYROID ACTIVITY

The minute amounts of iodine which are to be found in the circulating blood exist in two forms, inorganic iodide and protein bound iodide (P.B.I.),⁴⁰ the latter often being referred to as hormonal iodide since it is probably thyroxine in combination with a specific fraction of the plasma proteins. The circulation of these two forms of blood iodide is controlled by mechanisms which fix them in characteristic sites⁴¹. The inorganic iodide is rapidly withdrawn from the circulation and fixed by the thyroid gland while the P.B.I. is mainly taken up by the liver and the skeletal muscles.⁴² The laboratory work necessary for the determination of P.B.I.⁴³ is complicated and time consuming so that it is of limited application in clinical investigation. The normal level of P.B.I. in man is between 4 and 8 micrograms per 100 cc.⁴⁴ with much higher figures in thyrotoxicosis and almost zero values in myxedema.⁴⁵

The introduction of radioactive iodine, first as a diagnostic and later as a therapeutic measure in thyroid disease, has added enormously to our knowledge of normal thyroid physiology. Of the various isotopes of iodine, I¹³¹ which has a half-life of eight days has proved to be the most useful. The first studies in this field were made by Hertz and his associates in Boston in 1938⁴⁶, Hamilton and Soley in California, 1939⁴⁷ and Leblond and his co-workers in Paris and later in Montreal, 1940.⁴⁸ Hertz and his associates have shown that after the administration of radioactive iodine, the normal thyroid collects far more than does any other tissue in the body,⁴⁹ the percentage collected reaching a maximum in one to three days. It must be emphasized that this is the fate of a physiological dose of iodide. If an ordinary intravenous injection of

inhibition by the cerebral cortex might lead to an imbalance of the hypothalamic centers, with a resulting increased stimulation of the anterior pituitary and an outpouring of T.S.H. Heinbecker⁶⁶ has at-

The activity of the thyroid gland can be reduced by many agents. Perhaps the most direct is that of surgical ablation, but next to this roentgen irradiation is a direct method of causing partial destruction of the gland. Soley⁶⁷ was able to render patients with hyperthyroidism euthyroid, i.e., of normal thyroid function, by administering 150 r daily for six days. Many workers in this field have obtained equivocal results from irradiation of the thyroid, probably because dosage was not suitably controlled.

There is some evidence in support of a direct relationship between the thyroid and ovaries and testes, although there is much clinical observation to suggest such a connection may well be nonspecific. Hyperthyroidism is often accompanied by an increase in libido, myxedema invariably by a decrease. The reverse mechanism, i.e., the effect of sex hormones on the thyroid, appears to work almost exclusively through the anterior pituitary.⁶⁸ Large doses of estrogens markedly reduce thyroid activity and this can be shown to be accompanied by a diminution in the amount of circulating T.S.H.

Goitrogens.—Iodine Deficiency and Endemic Goiter.—The association of goiter with a lack of iodine in the diet has been observed from time immemorial. At intervals through the ages iodine has been employed as a prophylactic and there is a record in Egyptian hieroglyphics of the treatment of goiter by burnt sponge. In the Great Lakes district of North America, in Switzerland and in South Island, New Zealand, endemic goiter is widespread. One prime factor which all these districts have in common is the low concentration of iodine in the water. Careful surveys have been made in many of these regions, e.g., McCarrison⁶⁹ in India, which bring out the fact that this patchy distribution is probably due to local differences in the diet and sanitation of the population. The nature of endemic goiter has been thoroughly studied and most clearly in early

per cent of girls present such an enlargement. At puberty the goiter is prominent⁷⁷ but as time passes it is common for it to diminish in size in the male sex while persisting in the female. In the adult woman such a gland is liable to enlarge during pregnancy and by the fourth decade it is often discovered to have become nodular. These nodules may be of a degenerate nature and they tend to degenerate in size sometimes under pressure of the colloid in the cysts may alter and occasionally there is hemor-

rhage into one of them. The last chapter in this natural history reveals a patient with a large multinodular, cystic, colloid gland—the *pudding-stone* goiter of German authors.

As a result of extensive clinical observation and animal experiments, McCarrison⁷⁸ working in India differentiated between two main types of endemic goiter; the one found in mountainous areas, the other in the lowlands. The mountainous variety first appeared in childhood as a diffuse enlargement of the gland which was poor in colloid. It continued to grow slowly but steadily until the age of 60, becoming nodular in the process. It rarely gave rise to thyrotoxicosis and in the event of pregnancy the mother might be precipitated into a hypothyroid state, giving birth to a cretin. This variety of goiter was more prevalent when the water supply was contaminated with feces. In contradistinction the lowland type was a diffuse colloid goiter commonly occurring at puberty and tailing off at 25 to 30 years. If it was very endemic the sex ratio might be equal and thyrotoxicosis frequently developed. This type of goiter, McCarrison attributed to an excess of lime in the district.

Cabbage Goiter.—In 1928 Chesney⁷⁹ discovered that rabbits fed on a diet consisting largely of cabbage, developed goiters. The longer cabbage was given the larger was the goiter, and microscopically there was hyperplasia of the gland without colloid in the follicles. At necropsy the suprarenals were also found enlarged and it was occasionally noticed that the rabbits developed exophthalmos. On further investigation it was shown that the larger the goiter, the lower the basal metabolic rate.⁸⁰ Finally, Lugol's iodine when given to normal rabbits caused a temporary lowering of the B.M.R. and colloid storage in the thyroid; when given to these goitrous rabbits it elevated the basal metabolic rate and the animals became emaciated and died. The glands showed areas of hyperinvolution like colloid adenomas in a generally hyperplastic stroma.⁸¹ This is reminiscent of the Jödbasedow of Switzerland, thyrotoxicosis supposedly induced by the giving of iodine to a patient with a simple nodular goiter. McCarrison⁸² confirmed the production of cabbage goiter in rabbits in India, at the same time showing that the excretion of iodine in the urine was inversely proportional to the size of the gland.

In Australia, Kennedy and Purves⁸³ showed that the giving of *Brassica* seeds to rats had the same goitrogenic effect as cabbage in rabbits. They discovered that these goitrous rats showed pituitary changes: rapid increase in the number of basophil cells with hyalinization, vacuolation and formation of signet-ring cells with a simultaneous decrease in the acidophil cells. A tentative suggestion was made that the basophils might be the source of thyroid stimulating hormone.⁸⁴ Finally they found that *Brassica* seed had no effect on the thyroid in hypophysectomised rats, moreover if hyperplasia of the thyroid was already present, removal of the pituitary caused the goiter to diminish and colloid to reappear in its follicles.⁸⁵ Astwood⁸⁶ has recently isolated a

goitrogenic factor from turnips and cabbage seed which he also finds distributed throughout the mustard family. It is 1.5.vinyl 2.thio-oxazolidone and has one-fifth the activity of thiouracil.

Sulfonamides.—In 1941 the McKenzies⁸⁷ found that the administration of sulfaguanidine to rats for a prolonged period also had a goitrogenic effect, producing an enlarged hyperplastic thyroid, free from colloid, accompanied by a lowered basal metabolic rate. This discovery heralded a new era in the treatment and understanding of hyperthyroidism. The McKenzies in Baltimore,⁸⁸ Kennedy in New Zealand,⁸⁹ and Astwood in Boston⁹⁰ all made valuable contributions to this field during the next three years. Astwood investigated the action of many of these antithyroid drugs⁹¹ and was responsible for the introduction of thiouracil as a therapeutic agent in 1943. Before attempting to describe the manner in which thiouracil produces its effect it will be helpful to describe one other type of antithyroid substance.

Thiocyanate.—Potassium thiocyanate, which was previously used in the treatment of hypertension, may produce enlargement of the thyroid, decrease the gland's uptake of iodine and lower the basal metabolic rate.^{92, 93} McGinty's work⁹⁴ suggests that potassium thiocyanate forms a stable compound with iodine, this prevents the iodination of tyrosine and thyroglobulin. Thus the thyroxine level in the blood falls, and lacking its stimulus the anterior pituitary puts out more thyroid stimulating hormone and the thyroid becomes hyperplastic.

Administration of excess iodine will prevent these changes taking place because, although the thiocyanate prevents the usual concentration of iodine in the thyroid gland, sufficient diffuses through from the blood stream to allow thyroxine manufacture to continue.⁹⁵

Thiouracil.—The actual mechanism by which thiouracil inhibits the manufacture of thyroxine has not been determined although already a vast literature has grown up on the subject.^{96, 97} The active radical is the thiocarbonamide grouping and a great many variants have been used experimentally and clinically. Thiouracil does not inhibit the accumulation of iodide by the thyroid gland but it does prevent the production of thyroxine; thus the patient has a lowering of the basal metabolic rate while the gland becomes microscopically hyperplastic, presumably stimulated by the pituitary. Various specific enzyme systems which are necessary for thyroxine formation have been thought to be inhibited by thiouracil: cytochrome-oxidase,⁹⁸ tyrosinase⁹⁹ and peroxidase;¹⁰⁰ experimental work has not finally incriminated any one of them. Astwood's¹⁰¹ review of this subject should be consulted for further information.

Iodine.—Iodine has no effect on the thyroid function of a normal,

and their only merit lies in the amount of available iodide; thus 30 drops of Lugol's solution is equivalent to $4\frac{1}{2}$ grains of potassium iodine or 4

grains of sodium iodide.¹⁰² If it is completely absorbed, one drop of Lugol's solution or 6 mg. of iodine per day will produce the maximum effect. After approximately twenty days the effect of the iodine begins to wear off, if continued it may even augment the thyrotoxicosis. Robertson¹⁰³ has analysed four different types of response to iodine medication in hyperthyroidism as measured by the B.M.R. In the first type the B.M.R. falls gradually to normal, in the second there is a partial fall to a new level which is then sustained, in the third there is a sharp fall followed by a sharp rise to the original B.M.R., while the fourth and rarest type exhibits a rise in B.M.R. The interpretation of the effect of iodine in hyperthyroidism is still unexplained. Possibly the excess iodide in the gland favors the storage of thyroxine as thyroglobulin or it may inhibit the production of T.S.H. by the pituitary. Even when administered concurrently with thiouracil, iodine causes colloid storage and involution of the gland. Means¹⁰⁴ has postulated a dual role for iodine: one, iodinating or nutritive, the other involuting.

The Vitamins.—The interrelations between thyroid function and vitamin metabolism have been reviewed by Drill.¹⁰⁵ There is good evidence that in hypothyroid states carotene is not synthesized to vitamin A, while a deficiency of vitamin A leads to thyroid overaction.¹⁰⁶ McCarrison was the first to report thyroid hyperplasia in pigeons on a diet of polished rice. Clinically thyrotoxicosis increases the requirements of vitamins B₁, B₆ and pantothenic acid. Scurvy produces a hemorrhagic enlargement of the thyroid in animals and in cases of hyperthyroidism more vitamin C is used in the body. There is thus ample experimental evidence for the administration of large doses of vitamins A, B and C to patients with thyrotoxicosis.

Thyroxine.—The administration of thyroxine to the intact animal produces regressive changes in the thyroid gland similar to those following hypophysectomy. The balance between anterior pituitary and thyroid is a delicate one and it is possible that thyroxine may directly inhibit the action of thyroid stimulating hormone upon the thyroid,¹⁰⁷ as well as depressing the production of T.S.H. by the anterior pituitary. Cope¹⁰⁸ has shown that the presence of a hyperfunctioning adenoma of the thyroid gland will depress the activity of the remainder of the thyroid.

In addition to all the goitrogenic factors which have been mentioned there are three other ways in which thyroid activity may be reduced in man: (1) *Surgery* offers a ready means of lowering the output of thyroxine by an amount which can be accurately determined. (2) The administration of a therapeutic dose of *radioactive iodine* will also destroy thyroid tissue in proportion to the amount which is retained by the gland. This amount can in part be determined by the percentage uptake of a tracer dose and also by assessing clinically the approximate size of the gland. Finally (3) *thyroiditis* whether of the chronic inflammatory type associated with the name of Riedel, or more especially if of the lymphadenoid type of Hashimoto, will in time reduce the functioning amount of

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THE SURGICAL PHYSIOLOGY OF THE BREAST

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Abnormalities in the physiology of the breast certainly play a great role in the diseases of the breast. We have come to realize this fact not because we know much about the physiology of the breast, for we do not, but because a whole series of clinical observations relating hormonal effects to clinical disease in the breast have made us aware of it. Clinical empiricism is leading us toward an understanding of normal physiology.

As yet it has not led us very far, however. We know that the pituitary, the adrenals and the gonads are all concerned in the control of the growth and the function of the breast. But our knowledge of the mechanism by which the pituitary and adrenals affect the breast is only theoretical, and will have to await further progress by the chemists in the separation of these hormones. The gonadal hormones, concerning which we have a good deal of practical knowledge as to their effects on the breast, must be considered individually.

The *estrogens*, or ovarian follicular hormones, make the mammary epithelium grow. This fundamental estrogenic effect has been most extensively studied in the mouse (Haagensen and Randall). The effect varies somewhat with the strain of mice used, but the amount of epithelial proliferation that can be produced by the injection of estrogen in both female and male mice is striking.

We are now beginning to see a similar evidence in the human breast, female as well as male, with the widespread use of estrogens therapeutically. The administration of estrogen for gonorrheal vaginitis in infants produces temporary mammary growth. It is also a well established clinical fact that the administration of estrogen to adult females will make the breasts enlarge. We have studied a number of adult female breasts microscopically after long-continued estrogen therapy. They show essentially the same intense epithelial proliferation that we have been accustomed to see in the mouse breast. In the human breast the form which the proliferation takes is more varied than in the mouse breast, and includes virtually all the forms of epithelial growth that we see in surgical specimens of breast disease, including adenosis, intraductal papillary proliferation, cystic disease, and even carcinoma (Auchincloss and Haagensen). We have also studied several adult human male breasts following estrogen therapy, and have seen in them proliferation of the epithelium, and carcinoma. Similar reports of the

development of carcinoma of the male breast as the result of long continued estrogen treatment of prostatic carcinoma are beginning to appear from other clinics (Guardini).

The *androgens*, derived from the testicle, have in general a restraining effect upon the growth of normal mammary epithelium. In mice this is evidenced by an inhibition of the growth of the breast in female mice heavily treated with testosterone, and a diminution in the expected incidence of spontaneous mammary carcinoma (Nathanson and Ander-vont). For the human female breast adequate microscopical evidence bearing on this question is not yet available. There is some suggestion that the administration of testosterone diminishes the cyclical engorgement of the breast, but we know that the cyclical changes are vascular rather than epithelial.

Our greatest handicap to better understanding of the physiology of the ovarian and testicular hormones is our imperfect knowledge of the manner in which they are stored, broken down and excreted. Much interesting research is now under way concerning these questions and we may hope that the chemists will in the near future give us information that will be of practical value in guiding us in our clinical use of these hormones. For the present all that we can do is to review the results of the empirical use of these hormones in the various diseases of the breast.

ABNORMAL ENLARGEMENT OF THE BREAST

Prepubertal Enlargement.—It is not rare for female children of 10 to 14 years of age to develop enlargement of one breast well in advance of enlargement of the other. This need be no cause for alarm and requires no treatment.

In boys, just before or at the age of puberty, there is occasionally abnormal enlargement of one or both breasts. It takes the form of a discoid mass beneath the areola, which may be somewhat firm, and is often tender. Microscopically these lesions consist of proliferating ducts. Nathanson (1942) has shown that there is an atypical urinary excretion of estrogens and 17-ketosteroids in these patients, indicating an estrogen imbalance. Surgeons have often excised these lesions, quite unnecessarily we believe, for if nothing is done they will regress spontaneously after some months.

Postpubertal Enlargement.—In the adult female the breasts vary so much in size that it is difficult to define what is abnormal. A majority of women have slight differences in the size of their breasts. In a few, undeniable hypertrophy occurs, and one or both breasts enlarge strikingly. Such enlargement must be of hormonal origin, but we have no understanding of the exact nature of the hormonal imbalance. We have not attempted to treat such abnormalities with hormones, but advise plastic operations to correct the deformity when it is too obvious. Microscopically some of these very large breasts contain normal glan-

dular elements, but in most of them the glandular structure is underdeveloped and the bulk of the tissue is made up of fat and stroma.

In older men, between the ages of 45 and 65, enlargement of one or both breasts may develop. The lesion resembles that occurring in boys at puberty. It forms a firm discoid mass beneath the areola. It is usually tender. Within six months to a year it will regress spontaneously. Microscopically these lesions show proliferation of ducts, with little or no acinar development. Nathanson (1947) has found changes in sex hormone excretion in these patients similar to those he found in adolescents with breast hypertrophy.

This lesion must, of course, be distinguished from carcinoma of the male breast. Carcinoma forms a nontender, hard, irregular mass, rather than a tender, firm, rounded, tumor. Carcinoma is usually abnormally fixed to either the underlying fascia or the overlying skin, while a hypertrophic mammary gland lacks retraction signs.

If it is decided that no treatment is required for simple enlargement of the male breast, as is our preference, it is wise to re-examine the lesion every few months until it has disappeared, in order to make certain that carcinoma is not being missed.

Hypertrophy of the breast in males has also been seen in association with chorionepithelioma of the testes (Gilbert), interstitial tumor of the testicle (Hunt and Budd, adrenal cortical tumors (Simpson and Joll), pituitary tumors (Moehlig) and cirrhosis of the liver (Edmondson, Glass and Soll).

FIBROADENOMATOSIS OF THE BREAST

Fibroadenomas and adenomas of the breast ordinarily occur in younger women, not infrequently developing in the first few years after puberty. They rarely originate after the menopause, but may persist as inactive and sometimes calcified tumors in old age. This age incidence, of course, suggests that fibroadenomatosis is in some way related to estrogen production, but Nathanson (1947) found no abnormalities in careful excretion studies in a series of these cases.

There is a very real racial predisposition to this disease, for it is inordinately frequent in young Negro women. In them multiple fibroadenomas often develop, a phenomenon which is decidedly less frequent in white women.

Neither estrogen nor androgen therapy has any apparent effect upon fibroadenomatosis. It is a far cry to relate the effects of these hormones upon fibroadenomas in rats (Heiman) to their effects upon human beings

FIBROUS DISEASE OF THE BREAST

Fibrous disease is a lesion occurring in the breasts of women, usually between the ages of 25 and 50, characterized by an abnormal and irregular engorgement, which is often painful, and proliferation of the

fibrous stroma of the breast to form nodules and sometimes discrete tumor masses. This proliferation is most often seen in the upper outer sector of the breast, and is not infrequently bilateral.

This is one of the most difficult lesions for the clinician to evaluate. He is usually attempting to assess a degree of increased nodularity. This, in most cases, will not require surgical investigation, but when the lesion is more localized and forms a somewhat discrete tumor he faces the hazard of confusing it with carcinoma and is forced to biopsy it. No lesion in the breast demands so much experience for its correct evaluation. The surgeon should not operate upon fibrous mastitis for it is a harmless lesion, yet he must never miss a carcinoma.

It may well be that we are including in our syndrome of fibrous mastitis several different clinical entities. If so, they have the common feature of showing on microscopical study nothing more than nonencapsulated areas of increased density of the fibrous stroma of the breast. The epithelial elements show no proliferation whatever.

This lesion must be the result of some hormonal imbalance, for it is often only a part of a syndrome including several other signs and symptoms of endocrine abnormality. These women sometimes have a hair distribution that tends to be masculine, including a good deal of hair on the breasts. They often have a lowered fertility or are sterile. Their menses are often abnormal. Taylor (1936) has emphasized the frequent association of disease in the pelvic organs with this breast lesion.

Unfortunately we have no real knowledge of the nature of the endocrine imbalance in these patients. Taylor (1942) and Nathanson (1947) have reported that studies of estrogen excretion and gonadotropic hormone assay have revealed no gross abnormalities.

Under these circumstances we have not attempted any hormonal therapy, fearing to do more harm than good. Fibrous mastitis has a very variable course, showing remissions and exacerbations, and usually subsiding by the time of the menopause.

CYSTIC DISEASE OF THE BREAST

Cystic disease occurs in the breasts of mature women more often in the later years of the child-bearing period. It is a complex pathological process including cyst formation and several types of accompanying epithelial proliferation. The disease sometimes involves all of both breasts, but ordinarily only a small sector of one breast shows grossly evident cysts. Since the cysts are certainly the result of some abnormality in the regulation of the growth of the duct or acinar epithelium we may assume that the disease has a hormonal basis.

The women who have cystic disease, however, do not as a rule show any other clinical evidences of abnormal hormonal function. Breast cysts appear and enlarge, or diminish in size or disappear, in an irregular way without any evident relationship to the menstrual cycle. There are not available any adequate studies which show abnormalities in hormonal metabolism in these patients.

Both estrogens and androgens have been much used therapeutically for cystic disease. We have not been convinced that either of these hormones has any demonstrable effect upon the course of the disease, and we do not employ them.

We have been for some years engaged in a long-term follow-up study of our patients with microscopically proved cystic disease, seeking to test the widely held hypothesis that cystic disease is a precursor of carcinoma of the breast. We have not as yet found an abnormally high incidence of carcinoma in our series of patients, and we therefore continue to treat cystic disease conservatively. Since it is our practice to investigate every definite breast tumor surgically, a patient coming to us for the first time with a cyst has the cyst, or cystic area of the breast, excised. This plan has the advantage of giving us reliable evidence as to the type and extent of the epithelial proliferation. If a tumor, which clinically seems to be a cyst, subsequently develops in such a patient we do not excise it but merely aspirate it. If aspiration obtains fluid and the tumor collapses and disappears we are content. If we can not get rid of the tumor by aspiration we are, of course, forced to investigate it surgically. We do not believe, however, that simple mastectomy is required for recurrent cystic disease.

ADENOSIS OF THE BREAST

A special form of benign localized proliferation of ducts and acini, that was called *sclerosing adenosis* by Ewing, is important because it may closely simulate carcinoma both clinically and microscopically. Adenosis of so minor a degree that it does not form a tumor and is seen only microscopically is a not infrequent incidental finding in the breasts of adult women. But occasionally it grows to form a definite tumor which cannot be distinguished clinically or in its gross appearance from carcinoma. Microscopically the distinction is evident enough to an experienced pathologist, but pathologists not entirely familiar with adenosis have often been led by its infiltrating character to call it carcinoma.

Adenosis is not associated with any clinical signs of hormonal imbalance, and we are not familiar with any excretion studies of patients developing it.

INTRADUCTAL PAPILLOMA OF THE BREAST

Intraductal papilloma, the lesion ordinarily responsible for serous or bloody discharge from the nipple, is not accompanied by any clinical signs of hormonal imbalance, and there are no reports of hormone excretion studies in patients with this lesion.

We excise these lesions locally for they are benign and do not, in our opinion, undergo malignant transformation. We do not treat them with hormones.

CARCINOMA OF THE FEMALE BREAST

Oophorectomy.—Over fifty years ago Mr. G. T. Beatson (1896), a surgeon in Glasgow, observing that mammary function is dependent upon ovarian influences both in animals and human beings, began to perform oophorectomy in women with carcinoma of the breast. He obtained striking palliation in occasional cases. This was the first indication that hormones are in some manner concerned with breast cancer.

Since then a great deal of experimental work, largely with mice in which the disease has, as in women, a high natural incidence, has proved that ovarian hormones play a definite role in the genesis of breast carcinoma. Suppression of ovarian function decreases the incidence of the disease in females, while the administration of large amounts of estrogen speeds up its development. These hormonal effects are subservient, however, to another factor, probably a virus, which is present in the

There are certain clinical data that suggest that abnormal ovarian function plays a part in the origin of breast cancer. The disease is indubitably more frequent in women who have not borne children than it is in those who have (Lane-Claypon). Olch showed that delayed menopause is abnormally frequent in women who develop breast carcinoma. Herrell reported that women coming to the Mayo Clinic with breast cancer had less often had oophorectomy earlier in life than those who came to the clinic without breast carcinoma.

On the other hand, excretion studies of estrogens and of 17-ketosteroids (Taylor and Twombly, 1943, Nathanson, 1943) have not shown any abnormality in patients with breast carcinoma.

Beatson's early efforts to palliate breast carcinoma by oophorectomy led to nothing very definite, although the operation was taken up by several surgeons, with the result that by 1905 Mr. H. Lett was able to collect reports of results in ninety-nine inoperable cases of carcinoma of the breast. Seventy-five of these patients were under 50 years of age. In this group 29.3 per cent were reported to have shown considerable though temporary improvement, chiefly of superficial lesions. Beatson himself, reporting his further experiences with the operation in 1911, was less enthusiastic. He had narrowed the indications for the operation down to a comparatively small group of patients who had not reached the menopause and whose disease was not acute. In these the favorable effects were temporary and chiefly concerned cutaneous and subcutaneous nodules.

The majority of surgeons remained unconvinced of the value of oophorectomy in carcinoma of the breast, and in the enthusiasm for radiation treatment which came on the scene during the next decade, Beatson's operation was given up.

Suppression of Ovarian Function by Irradiation.—The idea was

revived again in the early 1920's by Wintz at Erlangen and by Ahlbom in Stockholm, who suppressed ovarian function by irradiation. Wintz claimed good results, but Ahlbom was unable to find any definite proof of the value of the treatment when he surveyed his results in 1930. The method was taken up in Boston by Dresser and case series begun both at the Pondville State Hospital and at the Collis P. Huntington Memorial Hospital. Grantley Taylor (1939) has recently reviewed the experience and concluded that artificial menopause induced by radiation in patients with inoperable or recurrent carcinoma of the breast has a definite palliative effect in about one-third. Bone metastases respond best. In a series of forty-seven cases of operable carcinoma of the breast in younger women, in whom artificial menopause was induced as a prophylactic measure, Taylor found no increase in the survival rate.

Hormonal Treatment.—Recent attempts to influence the course of breast carcinoma by administering estrogens and androgens have produced some striking evidence that these hormones do have an important role in the disease. English radiotherapeutists were the first to use estrogens. In 1944, before a session of the Radiology Section of the Royal Society of Medicine, reports of results in 168 patients treated with stilbestrol were presented. Among the 100 patients under 60 years of age only 15 per cent showed any improvement, but among the sixty-eight patients over the age of 60, 47 per cent were benefited. In five of these patients the improvement was spectacular.

About the same time that estrogen was being tried therapeutically, several clinicians began to give testosterone to patients with breast carcinoma (Loeser, 1939; Farrow and Woodard, 1942; Fels, 1944; Prudente, 1945). It was at once apparent that this hormone is remarkably effective in relieving the pain due to bone metastases.

By this time it was obvious that the accurate assessment of the real value of estrogens and androgens in the treatment of breast carcinoma would require accurate and prolonged study of a great many patients. In order to achieve this as quickly as possible the Therapeutic Trials Committee of the American Medical Association, in the fall of 1947, undertook to sponsor a cooperative investigation of the question. A Subcommittee on Steroids and Cancer, consisting of Drs. Ira Nathanson, Frank Adair, Willard Allen and Earl T. Engle, was appointed. Under their guidance a plan of study and methods for collecting data were drawn up.

Four dosage schedules for testosterone propionate were selected, as follows:

- Schedule A: 25 mg three times a week
- Schedule B: 50 mg three times a week
- Schedule C: 100 mg three times a week
- Schedule D: 200 mg three times a week

Each investigator was asked to use Schedule C for one-half of his patients, and one of the other schedules for the other half of his patients.

Six different estrogens were selected for study and the dosage for each established on the basis of the data available to the Subcommittee concerning its estrogenic potency. These estrogens and dosages were as follows:

Diethylstilbestrol.	. 15 mg. daily
Ethinyl estradiol.	. 3 mg daily
Premarin	. 30 mg daily
Estradiol Dipropionate	. 5 mg two times weekly (I M)
Dienestrol	15 mg daily
Dimethyl ether of diethylstilbestrol	. 30 mg daily

The Subcommittee suggested that testosterone be used in patients of all ages whose predominate lesions were in the bones. Estrogen was to be used in patients over 60 years of age whose lesions were predominately in the soft parts. *No patient was to be treated with hormones whose disease might be amenable to surgery or irradiation.*

Forty-five different clinical groups collaborated so well in the study that by March, 1949, some 750 case reports were available for study by the Subcommittee. In 426 of these cases there was at least one follow-up report. From these data, and from our own experience with the use of these hormones in our own clinic, it is possible to draw some tentative conclusions.

Dosage Levels.—The dosages of testosterone that have been used have probably been larger than is necessary, because no differences were noted in the response to 50 mg. as compared with 200 mg. of the hormone given three times a week. A total dose of somewhat more than 3 gm. of testosterone is required for a maximum response. Time is also a factor in the response, two months at least of treatment being required for relief of symptoms.

With diethylstilbestrol, also, results were better in the patients receiving a total dose of 2 gm. or more. A greater number of patients responded subjectively after two months, and objectively after five months, of therapy, than did those treated for shorter periods of time.

Therapeutic Results.—The results of hormone therapy should be estimated on the basis of *subjective* as well as *objective* improvement. Subjective improvement is improvement in the patient's feeling of well-being, increased physical activity, and relief of pain with discontinuance of medication for it. Objective improvement is the shrinkage or disappearance of visible or palpable tumor nodules or masses, the healing of ulcerated lesions, and the regression of lesions evident by x-rays in soft tissue or bone.

The results in the cases reported to the Subcommittee are summed up in the following table.:

Result	Testosterone Propionate (285 cases treated)	Estrogens (144 cases treated)
Subjective Improvement	58 per cent	62 per cent
Objective Improvement		
Soft tissues	56 per cent	27 per cent
Bone.. . . .	18 per cent	17 per cent

All observers recognize the fact that it is too early as yet to discuss with accuracy the duration of either subjective or objective improvement. About 20 per cent of the testosterone treated patients who have been benefited in the Subcommittee's data have been helped for nine months or more. The duration of palliation by estrogens has been about the same as with androgen. Two patients of our own have been to a considerable extent relieved of bone pain by testosterone for eighteen months. In other patients only three or four months of relief have been obtained. We must expect that the benefits obtained are in all patients only temporary, and that the disease always eventually gets beyond control.

Associated Physiological Changes.—Although these hormones are often beneficial, they regularly produce associated physiological changes which are unpleasant and even highly distressing to the patients. Testosterone, when given in adequate dosages, produces hirsutism, coarsening of the skin and acne, masculinization of the facial expression, deepening of the voice, and stimulation of the libido. Hypercalcemia has been observed in a number of patients, and may quickly become so severe that intravenous infusions of 2.5 per cent sodium citrate are indicated.

Estrogens produce nausea in some patients when the treatment is begun, but this symptom almost always improves or disappears after a week or two. Uterine bleeding develops in at least one-third of the patients.

Both androgens and estrogens may cause salt retention and edema. This may lead to cardiac decompensation in elderly patients with pre-existing cardiac disease.

Both hormones are metabolic stimulants, and aside from an improvement in the patient's sense of well-being, often produce a rise in the hemoglobin, and a gain in weight, and improvement in appetite. The basal metabolic rate is occasionally increased. Muscle tone is improved.

The Mechanism of Palliation by Hormones.—It is easy to attribute a share of the beneficial effects of hormone therapy in breast carcinoma to the general stimulative effects to these substances. But when severe pain due to bone metastases is relieved, when carcinoma nodules in the skin disappear, when pleural fluid ceases to accumulate, and when metastatic masses in the liver decrease in size, we must postulate that there is to some degree a direct restraining effect by the hormone upon the growth of the carcinoma cells. We certainly do not know the mechanism of this restraining effect. But even though this growth inhibition is obtained in only a minority of the patients the validity of the phenomenon gives hope that an explanation may be found for it.

The relief of pain due to bone metastases does not necessarily mean that the lesion is regressing. Most of the bone lesions in patients under treatment do not show recalcification. In some patients one bone lesion may recalcify while other bone lesions show progressive osteolysis. We have observed the continued extension of an area of bone destruction over a period of many months during which pain was entirely relieved by testosterone.

Indications for Hormone Therapy in Carcinoma of the Female Breast.—There is today enough evidence to warrant the conclusion that hormone treatment with androgens or estrogens is an important supplementary weapon against breast carcinoma in women. Surgery and irradiation are superior in value because they are more effective and because they have fewer distressing attendant consequences. Hormone treatment should, therefore, not be given until both surgery and irradiation have been used to their full potency. Nor is it justifiable to administer hormones as a prophylactic measure.

Androgen is indicated for pain due to bone metastases only after irradiation will no longer control it. Irradiation is preferable as the initial treatment because it acts more surely and more quickly. Androgen is also indicated for women under the age of 60 in whom carcinoma growing in soft tissues can no longer be checked by irradiation.

Estrogen is indicated for women over 60 in whom pleural involvement, or widespread involvement of the lung parenchyma, or intra-abdominal metastases, develop. Irradiation is of no value in these forms of carcinomatous spread. Estrogen is also indicated for women over 60 with carcinoma growing in soft tissues which no longer responds to irradiation.

Once hormone treatment has been started it should be continued without interruption until the end. When one hormone is no longer effective it is sometimes worth while to try the other.

CARCINOMA OF THE MALE BREAST

The surgical physiology of the male breast differs a good deal from that of the female breast if we are to judge from the reaction of carcinoma arising in it to hormonal influences. Attempts to influence carcinoma of the male breast by giving estrogen or androgen have been unsuccessful. Treves discovered, however, that orchidectomy often produces dramatic regression of the disease. In one of his patients the relief of pain due to widespread bone metastases was almost immediate, and subsequently the ulcerated breast tumor regressed and healed over, the bone lesions partially recalcified, and the pleural effusion disappeared. Four and one-half years later the patient was still alive but with reactivated disease. In one of our own patients (F. A., No. 885639) who at the time of orchidectomy in February 1918 was gravely ill with a large primary breast carcinoma, satellite nodules in the skin, axillary metastases, metastases in the ribs and scapula, pleural effusion, rounded shadows in both lung fields and a large upper abdominal mass, there was almost complete regression of the disease. A year and one-half later the axillary lesion and the skin and axillary metastases have almost disappeared, he no longer has any pleural effusion and the lung shadows have regressed, the bone metastases have recalcified, and the abdominal mass has disappeared.

Responses of this kind are more dramatic than any that we have seen following the castration of females with breast carcinoma. They justify

orchidectomy for every male with breast carcinoma in whom the possibility of surgical cure appears unlikely.

CONCLUSION

Although our knowledge of the surgical physiology of the breast is still rudimentary, important advances have been made during recent years as the result of the study of breast carcinoma in mice and the hormonal treatment of breast carcinoma in human beings.

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THE DIAGNOSTIC AND PROGNOSTIC VALUE OF PULMONARY FUNCTION TESTS

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It must be emphasized at the outset that pulmonary function tests provide only a physiological and not an anatomical or bacteriological diagnosis. They may complement or supplement, but cannot replace a careful history and physical examination, or radiologic, bronchoscopic, bacteriologic and pathologic studies. It must also be understood that in some patients function studies may reveal *no* abnormalities although serious disease of the lungs may be detected by other diagnostic techniques. For example, physiological studies cannot be expected to recognize the presence of small areas in the lungs that are neither aerated nor perfused. Lesions such as fibrotic tuberculous cavities, cysts or carcinomatous nodules will not be revealed by physiological tests unless they occupy so much space that they reduce the lung volume below normal limits, or are so located strategically as to disturb pulmonary function.

However, in some instances, tests of function may identify pulmonary disease in the presence of relatively normal clinical or radiologic findings. In addition, these tests can provide a quantitative measure of pulmonary disability or reserve, which may prove to be useful in the evaluation of candidates for permanent forms of collapse therapy or surgical removal of lung tissue, both so far as immediate risk and ultimate useful existence are concerned. Function tests should also be useful in evaluating effectiveness of different types of surgical therapy in pulmonary disease.

Clinicians are eager to know which pulmonary function test is of greatest value as a diagnostic and prognostic aid. In our opinion, no single test can be so used to the exclusion of others. We believe that for some years to come, a battery of tests must be used. If the results of these are carefully correlated with the preoperative clinical impression, the pathologic diagnosis, and the postoperative course in a variety of patients, there may eventually emerge a simplification of the procedures now employed. The purpose of this article is to present a brief description of the various types of pulmonary function tests, and to illustrate

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by several case presentations how these may be useful to the thoracic surgeon.

What are the functions of the lungs and how may these be measured? The major functions of the lungs are to oxygenate the venous blood and to remove excess carbon dioxide. The mechanisms by which these functions are accomplished are *ventilation* (the process of supplying adequate numbers of alveoli with adequate volumes of fresh air each minute), and *diffusion* (the process of transferring oxygen and carbon dioxide across the alveolar-capillary membrane). However, pulmonary function cannot be considered separately from cardiovascular function since proper gas exchange between lungs and blood depends upon adequate pulmonary blood flow through functioning alveoli. Details of tests devised to measure each of these processes will be omitted since these are adequately described elsewhere.^{1, 2}

TESTS OF PULMONARY FUNCTION

Static Lung Volumes.—By maximal effort, a healthy adult is capable of inspiring about 3500 cc. from the resting expiratory level as a starting point (*inspiratory reserve*, formerly called complementary air); he is able to expire, by maximal effort, about 1000 cc., again beginning at the resting expiratory level (*expiratory reserve*, formerly called supplemental air). The sum of the inspiratory and expiratory reserves is the *vital capacity*, it is usually measured by instructing the patient to make a maximal inspiration and follow this at once by a maximal expiration. The inspiratory and expiratory reserves and the vital capacity are most conveniently measured and recorded with the ordinary clinical basal metabolism apparatus.

Even after a maximal expiration has been made, approximately 1500 cc. of gas (residual capacity or residual air) remains in the lungs.

based upon the following principle: When an individual is breathing air, the gas remaining in his lungs at the end of a quiet expiration (the sum of the expiratory reserve and residual capacity, sometimes termed the *functional residual capacity*), is

N_2 . Its volume is unknown.

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of alveolar gas (80 per cent of
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10 cc. in this case) is the
city, the expiratory

reserve (previously measured spirographically) must be subtracted to obtain residual capacity.

Significance of Static Lung Volume Measurements.—Vital capacity measurements in an apparently healthy individual may deviate from the group mean by more than 20 per cent and so there is considerable difficulty in evaluating data in the low normal range. The test is of more value when repeated serial measurements are made in any one patient; a change of 100 cc. or more may then be regarded as significant, if the patient is cooperative.

A subnormal vital capacity does not necessarily signify lung disease. Low values may be due to poor cooperation, unfavorable position, generalized muscular weakness, abdominal distention due to fluid, gas or masses, neuromuscular disease involving the respiratory muscles, diseases of the bony cage, obstruction in the airway, pain in the chest, or upper abdomen (pleurisy, fractured rib, operative incisions), tight circular strapping of the chest, or to congestion of the pulmonary vascular system.

The finding of a vital capacity in the normal range does not eliminate the possibility of pulmonary disease. It may remain normal in emphysema even though the usual honeycombed arrangement of the alveoli be largely broken down with resultant pulmonary insufficiency. It may remain normal in the presence of obstructive lesions because vital capacity, as ordinarily measured, does not involve a time factor; obstruction may increase the time and effort required to deliver the vital capacity without affecting the final volume expelled.

The importance of measuring residual capacity, in addition to vital capacity, is twofold: (a) It provides an estimate of the resting level of the chest, which is usually shifted toward the inspiratory position in asthma and emphysema. An increase in the residual capacity or a high ratio of residual capacity/total capacity does not necessarily signify structural disease of the lung but, in the absence of an obstructive element, it usually suggests the diagnosis of emphysema. (b) It enables the total lung capacity to be measured; total lung volume is usually normal in asthma and emphysema and subnormal in pulmonary fibrosis. Data for normal static lung volumes in different age groups, both male and female, are given elsewhere.⁷

Dynamic Lung Volumes.—*Rate, Depth and Minute Volume of Breathing.*—In clinical practice, rate alone is counted and depth and minute volume are either ignored or estimated. Tidal volume is usually estimated from the rate, because the volume of air which enters the alveoli in the process of ventilation is that which enters the alveoli; that which remains behind in the respiratory dead space (approximately 150 cc.) of the mouth, nose, pharynx, trachea, bronchi, etc., does not participate in gas exchange.

A simple example may suffice to illustrate the importance of measuring tidal volume: Assume that two patients each breathe 8000 cc./minute

but the first has a tidal volume of 1000 cc. and a rate of 8/minute, whereas the second has a tidal volume of 200 cc. and a rate of 40/minute. The first has an *effective* minute ventilation of $(1000 \text{ cc.} - 150 \text{ cc. dead space}) \times 8$ or 6800 cc., while the second has an *effective* minute ventilation of only $(200 - 150 \text{ cc.}) \times 40$ or 2000 cc. Thus quantitative measurement of tidal volume should be made whenever there is any doubt concerning the efficiency of the respiratory movements (for methods, see reference 3)

Maximal Breathing Capacity (M.B.C.)—The maximal ventilation attained following inhalation of 10 per cent carbon dioxide is only about 50 per cent of the M.B.C. and that following severe muscular exercise averages only 65 per cent. The maximal respiratory minute volume, or maximal breathing capacity, can best be determined by requiring the patient to breathe as deeply and as rapidly as he can over a period of 15 seconds, he should be permitted to choose his own rate and depth but must be urged continuously and emphatically throughout the test to breathe as hard and as fast as possible.

M.B.C. differs from vital capacity in that the latter represents the largest volume of gas that can be expired after a single maximal inspiration *without respect to time*, whereas the former is defined as the maximal volume of gas that can be breathed per unit time. The M.B.C. test is widely used as a test of pulmonary function but has serious limitations which must be borne in mind. First of all, it is an *over-all* test of the ability of an individual to move air in and out of his lungs at high velocity, it is not an *analytical* test since it cannot identify the factor or factors responsible for poor pulmonary function. Second, "normal" values differ widely in different laboratories since many types of apparatus (Tissot, Benedict-Roth spirometers, Douglas bag, respirometer) are used, and the resistance to air flow in each of these types varies tremendously. Third, there is considerable subjective element involved since a successful test requires that the patient hyperventilate almost to the point of exhaustion. Fourth, low values may be recorded because of many extrapulmonary factors, just as with the vital capacity test.

The M.B.C. test appears to have its chief usefulness as a simple test for the estimation of respiratory mechanical efficiency. When M.B.C. is greatly reduced in a cooperative patient who has a normal or near-normal vital capacity, respiratory obstruction or decreased lung elasticity should be suspected as a rule. The determination of the vital capacity test supplemented by a careful record of the time required for expiration, gives essentially the same information, with less discomfort to the patient. Another simple test involves the measurement of inspiratory and expiratory time during quiet breathing, an increase in this ratio above 1:1.3 suggests that mechanical difficulties are present in expiration.

Breathing Reserve—The difference between the M.B.C. and the minute volume of ventilation is termed the breathing reserve. As de-

finer, the breathing reserve must be decreased if factors exist which increase the minute volume of respiration or decrease the M.B.C. Since the minute volume of patients with pulmonary disease is rarely increased by more than 10 L./min. during rest, this factor rarely leads to important reduction in breathing reserve, and decrease in M.B.C. is more important clinically. In many patients, the breathing reserve correlates well with the degree of dyspnea and some have termed Breathing Reserve \times 100, the "dyspneic index."

M.B.C.

Intrapulmonary Gas Mixing.—Proper ventilation of the lungs depends not only upon proper static and dynamic lung volumes but also upon the even distribution or mixing of the inspired air within the lung. Poor distribution of air is most frequently observed in patients with (a) obstruction (asthma, etc.) in whom the airways to certain portions of the lung are narrowed excessively, and (b) emphysema, in whom the elasticity of some of the lung tissue is reduced. Elasticity is the property of matter to return to its resting state after deformation; active work on the part of the inspiratory muscles is required during inspiration to "deform" or expand the normally elastic lung tissue, while little or no work should be required to expand the flabby, inelastic, emphysematous alveoli. For this reason a large portion of the inspired air may be drawn preferentially into poorly circulated emphysematous areas, leaving normal alveoli relatively hypoventilated.

Poor gas mixing may often be detected by a simple test in which the patient breathes oxygen quietly for seven minutes and then makes a maximal expiration; if the nitrogen content of the terminal portion of gas so expired is more than 2.5 per cent, poor mixing is assumed.⁴ The basis for this test is that oxygen inhalation should be expected to wash practically all of the nitrogen out of *all* the alveoli of the lung if each breath of oxygen mixed thoroughly and evenly with the lung gas over the seven minute period. If poorly ventilated areas exist, these will retain some of their nitrogen during quiet breathing but will expel it during the forced expiration at the end of the test; thus the nitrogen concentration in the sample delivered at that time will exceed 2.5 per cent. This simple test is of value only if positive; for example, temporary hyperventilation may give false negative tests by washing nitrogen out of alveoli even in regions usually hypoventilated. More precise evaluation of intrapulmonary gas mixing requires more complicated tests, not suitable for general use, such as those of Darling et al.,⁶ Bateman⁷ and Fowler.⁸

Diffusion.—The rate of diffusion of oxygen across the alveolar-capillary membrane can be measured in normal individuals by the method of M. Krogh, which involves the inhalation of carbon monoxide in low concentrations.¹⁰ The diffusion factor can also be measured in patients in whom impairment of diffusion is the only factor causing pulmonary insufficiency. However, when uneven mixing is also present quantitative studies of the diffusion factor are unreliable. (This is because transfer of

oxygen across the alveolar-capillary membrane is not accomplished by an active secretory process, but by simple diffusion. The transfer thus depends, among other things, upon the attainment of a uniformly high alveolar oxygen pressure, which does not occur when mixing is inefficient.) There are several simple, semiquantitative tests of the diffusion

when the pulmonary blood flow is supposedly increased. The patient may exercise upon a treadmill, stationary bicycle, standard steps or simply by walking on the level at a measured rate. In the other, the resting patient is given 100 per cent oxygen and the rate at which his arterial oxygen saturation rises from 97.5 to 100 per cent is charted (oximeter test), when a diffusion barrier exists, the arterial oxygen pressure is no longer in near-equilibrium with the alveolar oxygen pressure and consequently the attainment of full arterial oxygen pressure and saturation will require more time.* If poor mixing is present, these tests are simply "over-all" tests of pulmonary reserve, without serving any analytical function.

Pulmonary Blood Flow.—The pulmonary vascular bed may be reduced in emphysema, by destruction or removal of pulmonary parenchyma, endarteritis, sclerosis, thrombosis or embolism. Vascular sclerosis or reduction in vascular bed does not necessarily mean that pulmonary

is flowing through a reduced vascular bed, the velocity of flow must be increased so that less time exists for gas transfer. Pulmonary blood flow, pulmonary arterial pressure and even pulmonary capillary pressure

they reveal an inadequacy of the pulmonary vascular bed, removal of some of the remaining vascular bed by lobectomy or pneumonectomy may precipitate right ventricular failure.

Arterial Blood Studies.—Study of arterial blood oxygen and carbon dioxide is useful as an over-all test of the ability of the lungs to perform their function, i.e., to oxygenate the venous blood and remove excess carbon dioxide.

Arterial Oxygen.—A few important notes regarding the performance and interpretation of arterial oxygen studies are:

1. Oximeters produced commercially at present measure only *changes* in arterial oxygen saturation and not *absolute* values; hence for accurate measurements, samples of arterial or "arterialized" blood must be used and chemical determinations of blood oxygen content and capacity must be made.

2. It is not permissible to use venous blood for oxygen studies and then

to estimate arterial oxygen saturation on such a basis; venous oxygen saturation has been shown to vary from 25 to 91 per cent at times when arterial oxygen saturation was normal.

3. Arterial oxygen saturation may be low in the absence of pulmonary disease if right to left-sided shunts exist (as in some types of congenital heart disease and in pulmonary hemangiomata).

Arterial oxygen saturation may be normal in the presence of serious pulmonary disease; in the latter instance, measurements of arterial oxygen pressure may be useful diagnostically, since the nature of the oxygen-hemoglobin dissociation curve is such that arterial oxygen pressure may fall significantly below the normal level with little change in arterial oxygen saturation.

Arterial Carbon Dioxide.—A few important points in the interpretation of arterial carbon dioxide values are:

1. An increased arterial carbon dioxide content may be found in the presence of either alkalosis or acidosis. Patients with high arterial carbon dioxide content must not be treated routinely as cases of alkalosis. Measurement of blood pH is of considerable value in the interpretation of these cases. Inability to excrete carbon dioxide by way of the lungs, as in pulmonary insufficiency, leads to accumulation of carbon dioxide in the blood (high blood carbon dioxide) but this is *acidosis* (acid retention, primary respiratory acidosis).

2. Patients with serious pulmonary disease may have high, low or normal arterial carbon dioxide content or tension. If an added stimulus to the respiratory centre is present and if the lung is capable of hyperventilation, the arterial carbon dioxide may be subnormal; if there is no extra stimulus to the respiratory center, or if the center is depressed, or if the lung cannot be hyperventilated for mechanical reasons, blood carbon dioxide will be elevated.

3. From the point of view of the surgeon, a high arterial carbon dioxide pressure preoperatively is a warning to remove as little functioning lung tissue as possible, for such a patient is usually incapable of compensatory hyperventilation.

ILLUSTRATIVE CASES

To illustrate both the value and limitations of pulmonary function studies, two case reports are presented briefly.

CASE I.—Patient J. K. was a 64 year old white man who had been under treatment for tuberculosis for the past six years. Chest x-ray one month before admission revealed increased infiltration in the upper third of the left lung. He was admitted to the University Hospital because of the possibility that a neoplastic process might be complicating the tuberculosis. Bronchial secretions showed no cellular evidence of carcinoma (Papanicolaou technic). It was impossible to obtain tissue for histological examination through the bronchoscope but a needle biopsy of the left upper lobe lesion was successful. The material was reported to

be a squamous cell carcinoma of a primary type, and surgical excision of the lesion was decided upon.

Pulmonary function studies were performed preoperatively; some of the results are recorded in Table 1. Under Static Lung Volumes, it is seen that the vital capacity was reduced by more than 40 per cent below the predicted value for a man of the patient's age, height and weight. This reduction could be due to extensive destruction of lung tissue but the measurement of total lung capacity revealed approximately normal values. Since it was known that both tuberculous and carcinomatous lesions were present in this patient's lungs, one of the limita-

TABLE 1

PULMONARY FUNCTION STUDIES UPON PATIENT J.K. (PREOPERATIVELY)

Test	Normal (Predicted) Values	Actual Values
<i>Static Lung Volumes</i>		
1 Inspiratory reserve	3070 cc	1280 cc
2 Expiratory reserve	770	1020
3 Vital capacity	3840	2185
4 Residual capacity	1730	3655
5 Total capacity	5570	5840
6 $\frac{R}{T} \times 100$	31%	62.5%
<i>Dynamic Lung Volumes</i>		
1 Respiratory rate	16/min	21/min
2 Respiratory tidal volume	500 cc	529 cc
3 Respiratory minute volume	8 L/min	11.1 L/min
4 Maximal breathing capacity	88.7	50
5 Breathing reserve	90-97%	78%
<i>Intrapulmonary Gas Mixing</i>	—	Poor
<i>Over-all Tests</i>		
1 Arterial O ₂ saturation	97.5%	90.2%
2 Arterial CO ₂ content (plasma)	59 vols %	71.2%
3 Arterial CO ₂ tension	40 mm. Hg	53
4 Arterial pH	7.42	7.39
5 Oximeter rate	52 sec	85 sec.
6 Oximeter increase	3.7%	6%
7 Treadmill	No dysp. or anox.	++ Dysp O ₂ sat. ↓ 6%

tions of measurements of lung volumes becomes apparent, namely that only rather extensive lesions can be detected with certainty by this technic, because of the wide variations among normal persons. In this patient, the diminished

increased pulmonary elasticity (as in emphysema) or of a combination of the two.

In this patient, analytical significant breathing capacity measurements of intrapulmonary gas mixing revealed definite unevenness in the distribution of the inspired air to the alveoli; this again suggests the presence of

emphysema, though it does not rule out asthmatic-like obstructive lesions. Because of the abnormality in gas mixing, diffusion across the alveolar-capillary membrane could not be estimated.

Arterial blood studies revealed a moderate degree of anoxemia, associated with a high plasma CO_2 content and tension. Since the arterial pH was reduced, the high blood CO_2 signified primary respiratory acidosis, due to CO_2 retention. In the absence of severe respiratory depression or of terminal diffuse pulmonary edema, respiratory acidosis of this type is usually due to pulmonary emphysema. The severity of the pulmonary disease in this patient was revealed by an exercise test upon the treadmill; while walking at only 1.6 m.p.h. for 2 minutes the patient experienced severe dyspnea and his arterial O_2 saturation fell 6 per cent.

The physiological diagnosis in this patient was pulmonary insufficiency, of a moderately severe type. Because of the finding of a high residual capacity, decreased inspiratory reserve, normal total capacity, poor mixing, anoxemia and respiratory acidosis, the most likely clinical diagnosis would be pulmonary emphysema. The patient was judged to be a poor operative risk.

However, because of the threat to life from the carcinoma, operation was performed. A left pneumonectomy was found to be necessary at operation. Postoperatively, the patient had severe dyspnea upon the slightest exertion. He died suddenly upon the twenty-fourth postoperative day. Autopsy revealed emphysema and edema of the remaining lung tissue.

Insufficient data exists at present for predicting the amount of lung tissue that can be removed safely from a patient with emphysema complicating other pulmonary lesions. Until such data accumulates, only minimal amounts of functioning lung tissue should be excised in any patient with pulmonary insufficiency due to emphysema.

CASE II.—Patient T. S., a 42 year old white woman, was admitted with a history typical of pulmonary hemangioma, including nosebleeds, multiple telangiectases of skin and mucous membranes, hemoptysis, cyanosis and a family history including some or all of these complaints. Radiologic studies revealed two shadows at the left border of the heart; it was not possible to be sure that the lesions pulsed independently of the heart. Cardiac studies were negative except for a soft systolic apical murmur.

Pulmonary function studies were performed upon this patient to determine

ment of diffusion (thickened membrane, etc.). However, inhalation of O_2 did not raise arterial O_2 saturation above 94.3 per cent, whereas in all except extremely severe cases of impairment of diffusion, O_2 therapy raises the saturation to 100 per cent. For these reasons, a diagnosis of disease of the pulmonary parenchyma is excluded in this patient and the presence of a right to left-sided shunt becomes almost a certainty. Strongly in favor of the existence of such a shunt

are two findings: (1) failure of arterial O_2 saturation to rise to 100 per cent during inhalation of O_2 , the venous blood passing through the hemangioma does not come in contact with functioning alveoli and hence cannot be oxygenated; (2) the decrease in arterial O_2 saturation that occurred during exercise, even during O_2 inhalation, venous blood from the exercising muscles contains less O_2 than normally and the portion of this which escapes oxygenation leads to a reduction in arterial O_2 saturation.

TABLE 2
PULMONARY FUNCTION STUDIES UPON PATIENT T S

Test	Normal (Predicted) Values	Actual Values
<i>Static Lung Volumes</i>		
1 Inspiratory reserve	1988	2120
2 Expiratory reserve	662	449
3 Vital capacity	2650	2570
4 Residual capacity	810	1216
5 Total capacity	3460	3746
6 $\frac{R C}{T C} \times 100$	23%	32.5%
<i>Dynamic Lung Volumes</i>		
1 Respiratory rate	16	26
2 Respiratory tidal volume	500	485
3 Respiratory minute volume	8 L/min	12.6 L/min
4 Maximal breathing capacity	(recent hemoptysis)	
5 Breathing reserve	—	—
<i>Intrapulmonary Gas Mixing</i>	—	Normal
<i>Over-all Tests</i>		
1 Arterial O_2 saturation	97.5%	84.9%*
2 Arterial CO_2 content (plasma)	59 vols %	46
3 Arterial CO_2 tension	40 mm Hg	33
4 Arterial pH	7.42	7.42
5 Oximeter rate	52 sec.	80 sec
6 Oximeter increase	3.7%	7.5%
7 Treadmill		†

* After inhalation of oxygen for thirty minutes, 94.3 per cent.

† No dyspnea, but arterial oxygen saturation fell 2 per cent even during inhalation of oxygen.

The function studies performed upon this patient led to a physiological diagnosis of right to left-sided shunt. They did not differentiate between possible types of shunts such as pulmonary hemangioma, atelectasis or congenital heart disease. In doubtful cases, cardiac catheterization or angiocardiology may be needed to establish the anatomic site of the shunt. In this patient, however, the history and ordinary radiologic studies were sufficient to establish the diagnosis and location of the hemangioma.

SUMMARY

The usefulness and limitations of pulmonary function tests have been discussed and illustrated. When used with intelligence and in conjunction with other diagnostic aids, physiologic tests are often of prognostic or diagnostic value to the thoracic surgeon.

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THE SURGICAL PHYSIOLOGY OF PERIPHERAL VASCULAR DISORDERS

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Ideally, in order to deal most effectively with any disorder, both from the standpoint of its prevention and treatment, the precise physiological alterations associated with the condition should be clearly understood as well as the etiological and pathological processes which bring it into being. In treating the established condition the aim obviously should be to safeguard the patient's life, to cure the disease if feasible, and, if not, to stop its progress, to conserve the affected part and restore it to as normal a functional state as possible. With reference to the peripheral vascular disorders these ideals are sometimes realized but often are impossible. All too frequently we are handicapped by lack of knowledge of the etiology, by incomplete understanding of the physiopathologic processes at play, by inability to cure the disease or to stop its progress, by irreparable morphological changes. Nevertheless, it is felt that considerable progress is being made towards better physiological restitution of the disordered circulation.

SURGICAL CORRECTION OF THE DISEASED OR INJURED ARTERY

Arteriovenous Fistula.—A number of examples in which treatment approaches the ideal can be cited. First, let us consider the problem of arteriovenous fistulas. The method of their occurrence is known. Most of them are traumatic in nature, a few are due to congenital defects, and, rarely, they result from perforation of the wall of a diseased artery into an adherent adjacent vein. Though there are undoubtedly many fine points of possibly considerable significance which are unknown, the basic physiological alterations associated with the fistula are well known, both the local effects in the involved limb and the remote effects upon the heart and general circulation. The indication for treatment is clear-cut. Means are available for testing before operation the adequacy of the collateral circulation. This is most important since operative obliteration may entail ligation of the affected vessels. Though these tests are not infallible they are generally reliable. In case the collateral circulation is found to be inadequate, measures such as sympathectomy may be instituted in an effort to increase the adequacy of the collateral bed, following which the tests can be repeated until they are found satisfactory. Further safety can be achieved by making certain that the limb maintains

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good color and warmth during a period of precise occlusion of the affected vessels at the time of exploration.

Once the fistula is obliterated the remote physiologic effects of the lesion are reversed, the cardiac output decreases, and the heart returns to normal size except in the unusual case of long standing in which some hypertrophy as well as dilation has been present. If the operative procedure necessitates ligation of the involved vessels and the collateral circulation is good, the local results in the affected limb are generally excellent. They are well nigh perfect if, as is quite commonly possible, the continuity of the artery is preserved by ligation and transfixion of the fistula or by lateral arteriorrhaphy, or if the continuity is reestablished after excision of the damaged portion by end-to-end anastomosis or by interposition of a free vascular transplant. Although the continuity of the vein may sometimes be maintained, experience has shown that no noticeable malfunction results from its ligation and this procedure is generally followed. This, then, is an ideal example of cure of the lesion, reversal of its physiologic effects and restitution of normal function.

Arterial Aneurysms.—The same ideal is not infrequently possible in the treatment of the related arterial aneurysms, especially in the case of traumatic lesions. The number of instances in which restitution of normal blood flow can be effected, particularly in large aneurysms resulting from arterial disease, should be appreciably increased by Blake-more's¹ suggestion of combining aneurysmotomy with the intrasaccular interposition of a venous transplant. Though the possibilities will vary widely according to the extent of associated injuries and the time interval before definitive surgery can be attempted, some of the acute traumatic injuries of large arteries should be similarly amenable to maintenance or reestablishment of normal blood flow.

Arterial Embolism.—Another example may be profitably considered in which ideal treatment of the local lesion is often possible but in which the underlying disease which is responsible for initiating the local difficulty cannot be handled so successfully. I refer to embolism of an artery so important to the nutrition of the limb that its continued obstruction will lead to gangrene. It is well known that the source of such emboli is generally from a thrombus arising upon the endothelium of the diseased heart and rarely from a thrombus developing upon an arteriosclerotic plaque or the injured intima of some proximal artery. The disastrous effect of the sudden block is readily apparent and the diagnosis and localization of the embolus is generally not difficult. If the obstructed portion of the artery is exposed, an arteriotomy performed and the embolus removed, the incision in the vessel properly sutured and anti-coagulant therapy continued until healing has been obtained, the chance of a perfect functional local result is excellent—provided the distal arterial tree has not already been irreparably occluded by thrombosis and provided the intima of the artery has not been permanently damaged by compression of the obturating embolus.

Experience has taught us that, by and large, embolectomies are apt

to be successful if performed early and unsuccessful if performed late. The interval of time between embolism and embolectomy is, of course, of no fundamental importance except in respect to the fact that the longer the interval the more apt is thrombosis of the distal arterial tree to take place and the more likely is the occurrence of local severe intimal damage at the site of the embolus. I have performed a femoral embolectomy four hours after embolism and found the entire distal tree solidly clotted and I have, on the other hand, performed a common iliac embolectomy over twenty-four hours after embolism and found no thrombus at all distal to the embolus. In the first case gangrene naturally followed; in the second, excellent full restitution of blood flow was established and maintained until death ensued from the underlying cardiac disease.

What factors are involved in this important matter of distal thrombosis? We have good reason to believe that, in the absence of intimal damage, intraarterial clotting almost never occurs if adequate blood flow is maintained, but is prone to occur if the blood flow is extremely reduced. Any measure which increases the efficacy of the collateral circulation should, therefore, be of value. Furthermore, it appears reasonable to assume that the onset of clotting of an artery through which only a trickle of blood is flowing must be related to the duration of the stasis, just as normal blood placed in a glass tube is almost never clotted within a few minutes but is invariably clotted a little while afterwards. In addition, one would expect that adequate heparinization would diminish for a time the chance of thrombosis of the artery with poor blood flow just as it prolongs the time before clotting occurs in the test tube. To provide the best chance for a successful arterial embolectomy, it would appear evident that an early diagnosis must be made, that a large amount of heparin be given immediately, that every effort be made to provide maximal vasodilatation so as to provide the best possible flow of blood into the distal artery through the collateral channels, and that operation be performed without delay. It is unnecessary to remove the embolus itself in those instances in which there has occurred embolism to an artery of such relatively little importance to the nutrition of the limb that no significant reduction in circulation results, or to an artery about which the collateral blood flow is so abundant that, with simple means such as anticoagulant therapy and induction of sympathetic paralysis, it becomes evident that perfectly adequate circulation is present.

Though in many cases of arterial embolism it is possible to obtain a perfect or near-perfect local functional result, we are unfortunately not capable of dealing so effectively with the primary cardiac disorder which usually initiates the disaster. All too frequently one succeeds with the acute obstructive difficulty only to have the patient succumb sooner or later to his heart disease or to subsequent fatal emboli. To be sure, anticoagulant therapy offers promise of diminishing somewhat the hazard of further embolic occurrences but more effective means of dealing with the diseased heart must be forthcoming if we are to render the over-all outlook of the patient more favorable.

Acute Arterial Thrombosis.—Can those methods of direct attack upon

the vascular lesion itself and reestablishment of normal circulation through the affected artery be applied to other conditions? I am convinced that they are applicable to acute arterial thrombosis, though I have not had an opportunity to apply these principles in this condition. In those instances of acute arterial thrombosis in which inadequate circulation persists because of the relatively important role of the obstructed artery, and cannot be rendered adequate by induction of local sympathetic paralysis and use of anticoagulants, it would seem reasonable that operation should be carried out with greatest possible haste. In this circumstance the procedure itself would necessarily be different from that employed in the case of emboli. Because of the underlying intimal damage it would not be sufficient to remove the thrombus and repair the incision in the artery. It is likely, however, that excellent results would obtain if the thrombosed segment were resected and a free vascular graft used to bridge the defect.

Re which I feel is of considerable importance in the treatment of acute thrombosis associated with of the arterial tree distal to portion and to interpose a long vein graft blood flow. Though I do not feel that routine arteriography real help in obliterative disease in general, I feel strongly that the experience referred to makes the study mandatory in all instances in which it is felt possible that only a localized segment of the arterial stem is occluded and that the distal tree may be patent. Though I have not encountered such a case since I learned of Holden's remarkable experience, I am certain that continued search will reveal a number of instances in which this principle can be applied with excellent results. It would appear worth while to study, with the same potentialities in mind, all patients who have had persistent annoying or disabling symptoms from circulatory insufficiency consequent to the traumatic disruption or thrombosis of an important artery, or by the immediate surgery necessary (ligation), or by late surgery required because of ensuing complications (aneurysm or arteriovenous fistula). Among those patients it is probable that a fair number may have maintained patency of the arterial tree distal to the point of obstruction or disruption and may be suitable candidates for bridging the defect with a vascular transplant.

THE VALUE OF SYMPATHETIC PARALYSIS

Obliterative Arterial Diseases.—With regard to the chronic obliterative arterial diseases which are so much more common in occurrence than those disorders previously mentioned, and so often disabling in their effects, we are unfortunately frequently confronted with a problem that is at present insoluble as far as perfect, or even good, physiologic rehabilitation is concerned. Here we are dealing with a progressive and often diffuse arterial disease which results in extensive obliteration

of the continuity of important arteries. As far as we know, the obstruction tends to involve the major vessel from the point of proximal occlusion so far distally that it is unlikely one could reestablish continuity by vascular transplantation, not so much because of the length of the obstructed segment but because any patent distal portion is apt to be so small in caliber as to make the procedure technically unlikely to yield a good result. Of course, there are exceptions such as those just considered where a limited obstructing thrombus develops rapidly or slowly upon a localized area of diseased intima. Fortunately, however, when the arterial tree is irreparably occluded we are often not in a hopeless situation.

Knowing the physiologic alterations in the arterial bed and the capacity for increasing or decreasing blood flow by stimulating or paralyzing the sympathetic nerve supply, we have means which are not infrequently remarkably effective. Not only can one study the effect of transient sympathetic interruption upon the circulation to the affected part, but he can also observe the influence which this procedure may have upon any complaints manifested, such as rest pain, sensory and motor disturbances, sensitivity to cold or intermittent claudication. By and large, such studies permit one to prognosticate fairly accurately the result which may be obtained from permanent sympathetic ablation. To be sure, they are not entirely reliable in every respect. In my experience it is extremely difficult to anticipate from studies of intermittent claudication made before and during temporary sympathetic paralysis the effect which sympathectomy may have upon this complaint. It is also evident from many observations that the lack of any demonstrable improvement in circulation during such transient sympathetic anesthesia does not invariably indicate that no improvement will follow sympathetic denervation. Hence, in selected instances, one can proceed with operation in such circumstances with the realization that some will be sufficiently benefited to save the extremity.

Certain other useful measures obviously must be utilized in obliterative diseases, such as insistence upon abstinence from tobacco in cases of thromboangiitis obliterans, proper care of the nails and skin of the affected limb, avoidance of injury to the part or exposure of it to extremes of heat or cold. Nevertheless, an effort to render the circulation maximal through abolition of sympathetic impulses remains a most important therapeutic tool for increasing the function of the part and for remedying the manifestations of ischemia. The results will vary according to the extent of the ischemic damage and the capacity of the part for improvement in circulation through release of vasoconstrictor impulses. They will vary from absolute failure ending in major amputation to the most gratifying relief of pain, healing of ulcerated lesions, saving of limbs threatened by gangrene or limitation of tissue loss, and general restitution of reasonably satisfactory circulation. Though I know of no objective data of statistical significance concerning this matter, until such data becomes available it would seem

reasonable to proceed upon the assumption that the resultant maintenance of a state of maximal or near-maximal circulation should diminish the likelihood of further arterial thrombosis and the development of ischemic disasters and should offer the patient some insurance for the future

Vasospastic Conditions.—With regard to those disorders characterized either by more or less continuous or by episodic spasm of arteries, such as acrocyanosis, the large group of ill-defined vasospastic conditions and Raynaud's disease, generally satisfactory physiologic results can be anticipated from permanent release of vasoconstriction through sympathetic paralysis. Here, too, the results are not constant for all the vasospastic conditions or for all patients suffering from any one of them. By and large, the early and late results have proved excellent in acrocyanosis, in cases of hyperhidrosis, and in the large miscellaneous group we chose to classify as ill-defined vasospastic conditions. In Raynaud's disease the results are certainly better in those patients treated before the onset of trophic changes such as bony atrophy, scleroderma, extensive ulceration or gangrene. It is also true that the results shortly after treatment are better than the late results after the passage of many years. Nevertheless, the over-all results appear at this date to be generally most gratifying.

Posttraumatic Vasomotor Disorders.—I have previously referred to the importance of early diagnosis if treatment is to be expected to bring about the best possible restitution of good function. Nowhere is this more evident than in the large group of reflex difficulties which can perhaps best be designated as the posttraumatic vasomotor disorders. Everything suggests that the signs and symptoms in these conditions are due to the effect of some local injury or irritative focus and are maintained by some reflex disturbance involving the sympathetic nervous system as one component of the arc. Many precise and clever theories have been postulated to explain the disorder fully but it has not been possible to prove conclusively the validity of any one of them. A number of therapeutic measures have proved their worth. It appears certain that aside from other measures it is always necessary to obtain the patient's cooperation, to make him sufficiently optimistic in regard to the outcome to be willing to carry out vigorously the program outlined, to treat any edema present by proper rest, elevation, and use of elastic support when the limb is dependent, and to have the patient exercise actively the affected part. In some, a trigger zone can be identified; anesthetic infiltration or excision often yields dramatic effects. Any existing psychoneurosis must be dealt with. In some, induction of temporary sympathetic anesthesia is very effective. Still others require sympathetic denervation. If the disorder is recognized early and treated properly and actively, the results are, by and large, excellent. Treatment is much more difficult, prolonged, and attended by more failures if it is begun after the condition has existed for a long time. In contradistinction to the varying manifestations and the

multiplicity of considerations in treatment which prevails in this group of disorders, the related condition of major causalgia fits precisely into a recognized pattern and can almost invariably be cured by periodic temporary sympathetic anesthesia or by permanent sympathetic denervation.

Methods of Inducing Temporary Local or General Vasodilatation.—There are many methods by which local or general vasodilatation can be temporarily induced. The application of heat to the body, especially if combined with ingestion of alcohol, often effects a striking vasodilatation in the extremities. The same effect can be secured frequently by diathermy to the trunk, by immersion of uninvolved limbs in warm water, by general anesthesia, hypnosis, barbiturate narcosis, and by the administration of chemical autonomic blocking agents such as tetraethylammonium chloride or Priscol. Vasodilatation in the lower extremities may be achieved by spinal anesthesia. Vasodilatation restricted to the affected limb can be secured by the use of anesthesia of the appropriate portion of the sympathetic chain or of the somatic nerves, by application of heat to the limb, or by the intraarterial injection of a variety of agents such as prostigmine or procaine. Intraarterial injection would appear unwise for routine use. Local application of heat seems clearly contraindicated whenever there is significant ischemia due to obliterative or obstructive arterial disease. The blocking of somatic nerves has the disadvantage of sensory and motor paralysis. Hence for all practical purposes the only method generally applicable for the production of local vasodilatation is sympathetic anesthesia.

It has long seemed evident to many of those interested in peripheral vascular disorders that the production of local vasodilatation was preferable to the production of general vasodilatation. I believe it has been the general experience when any given subject has been tested under controlled conditions that a greater degree of vasodilatation has resulted from local sympathetic paralysis than from any method producing general vasodilatation. DeBakey and his associates have attempted to explain this observation on the basis of hemometakinesia and have offered some evidence in support of the hypothesis. Though most of the methods mentioned have some definite usefulness, at the present time I prefer in general to use local sympathetic procaine blocks when temporary release of vasoconstriction seems indicated.

The Production of Permanent Sympathetic Paralysis.—When permanent sympathetic paralysis is desirable, operative preganglionic sympathetic denervation is the only practical method available. In general, the results have been excellent and the effect relatively permanent. To be sure, cases of extensive sympathetic regeneration have been observed—more frequently after operations for the denervation of the upper extremity than after lumbar ganglionectomy. Any return of sympathetic function in the lower extremities appears to be slow and incomplete. Though the likelihood of return of sympathetic function in the upper extremities apparently increases as the years pass by, the long-term

effect of the operation seems thus far to be fairly satisfactory. It is evident that the introduction of preganglionic decentralization of the chain by Smithwick and Telford and Smithwick's later suggestions of section of the anterior roots in their intradural portion and the encasement of the decentralized chain in a silk cylinder have added greatly to the effectiveness and permanency of the sympathetic paralysis. In contrast to the generally good results obtained with this procedure, the old stellate ganglionectomy or upper dorsal ganglionectomy was often followed by rapid return of sympathetic function and similar results are not infrequently seen today when the upper dorsal and lower cervical ganglia are excised during the course of total sympathectomy and aplanchnicectomy for hypertensive disease.

Chemical Autonomic Blocking Agents—It is impossible to be sure what the future of the chemical autonomic blocking agents will be. Numerous favorable reports have been published concerning their use in obliterative and vasospastic arterial disease, reflex disturbances, thrombophlebitis, hypertension and the like. I have had only a limited experience with these agents but have found them more useful in acute thrombophlebitis than in other conditions. I have not had as good results from their use in a limited number of cases of minor causalgia and related disorders as I have obtained from employment of sympathetic blocks in a much larger group of patients. It would appear that there are certain inherent disadvantages. It is unlikely that any method producing general vasodilatation can be quite as effective in improving blood flow locally as the induction of local vasodilatation. From our experiences in hypertensive patients treated by total sympathectomy it is difficult to conceive of any agent producing complete sympathetic paralysis without bringing about some degree of postural hypertension, and any significant lowering of blood pressure will vitiate in part the increase of blood flow brought about by the vasodilatation. The drugs presently available, and particularly tetraethylammonium chloride, are not infrequently attended by unpleasant and sometimes alarming side-effects. Similar new agents are being constantly produced and studied and it is conceivable that some will result in many fewer such reactions. Everyone looks forward to the continued effort to add other blocking agents to those now available and to the continued study of their physiologic effects and the results of their clinical application. Nevertheless, I have the conviction that sympathetic blocks and sympathectomy will remain useful tools in the treatment of the peripheral vascular disorders. One could speculate that if the autonomic blocking agents prove their worth in such conditions they will have maximal usefulness in those disturbances in which it has been established that one or a series of sympathetic procaine blocks is often remarkably effective, and in the chronic vasospastic disorders like Raynaud's disease in which the circulation is generally normal and in which the periods of spasm are limited to periods of emotional excitation or exposure to cold.

OTHER SURGICAL METHODS FOR IMPROVING FUNCTION OF THE DISORDERED EXTREMITY

Treatment of Varicose Veins: Superficial Femoral Vein Ligation and Obliteration of Existing Superficial Varices in Postphlebitic Limbs.—Proper treatment is obviously clarified if the physiologic disturbance which characterizes a disorder is well understood. No better example can be cited than that of varicose veins. The task of treatment was immediately simplified once it became recognized through the teaching of Homans and others that a varicose vein is not simply a prominent vein or a tortuous vein but is one in which, because of incompetent valves, the blood flow is retrograde when the limb is dependent. With this understanding of the nature of the disorder, the indication and type of treatment was reasonably clear once the diagnosis was carefully established. In general, concern about the adequacy of venous return by other routes ceased to be a major problem. By its very nature the varicose vein could not possibly contribute to venous return when the limb was dependent, but, on the other hand, would result in venous stasis. Hence its obliteration would only result in improved function. It would seem entirely likely that those cases of disastrous increase in venous stasis following ligation and injection of "varicose veins," so often used as a warning that before treating such cases one must first establish the adequacy of the deep venous return, were in reality instances in which dilated collateral veins with normal valves and normal flow were incorrectly assumed to be varicose veins and were sacrificed when they were performing proper function. A second possibility is, of course, that some may have been instances of true varicosities and that treatment was attended by associated inadvertent extensive thrombosis of previously normal veins. The necessity to use every measure, such as frequent active exercise of the limb by walking and elevation of the limb when resting, in order to prevent extension of the thrombus into normal venous channels is so well recognized it hardly requires comment. That the treatment of varicosities is generally beneficial even if the effectiveness of the deep circulation is greatly reduced is evident from the improvement often noted when varices are obliterated in patients in whom they have developed in a limb in which an old deep thrombosis is known to have been present.

Though such treatment has not enabled us to restore perfect function in postphlebitic limbs, there can be no question that marked improvement is often noted after superficial femoral vein ligation and obliteration of existing superficial varices. The rationale of such vein ligations is based upon the early observations of Homans and others that the thrombosed vein invariably, or almost invariably, undergoes recanalization. I have personally never divided such veins without finding evidence of recanalization. The recanalized vein is an incompetent one since no effective valves are present to prevent regurgitation. This incompetence can be readily demonstrated at the time of ligation by roentgenographic visualization of a retrograde injection of an opaque medium. I have on a

number of occasions performed such tests and found that the dye descends down the length of the recanalized vein.

Radiologic Method for Demonstrating Incompetency of the Valves of the Femoral Vein.—The use of another radiologic method illustrates the potential value of precise studies of a functional nature in the recognition of disordered circulatory states and their proper treatment. I recall with what enthusiasm I read the report of Luke³ in 1941 describing a technic which had permitted him to establish incompetency of the valves of the femoral vein as the explanation of chronic swelling of a lower extremity in one of his patients. By injecting 30 cc. of 70 per cent Diodrast into the femoral vein during proximal digital occlusion he was able to show that the dye descended into the leg on the affected side but only to the first valve station in the uninvolved extremity. He did not mention any treatment he thought indicated. It immediately occurred to me that one might obtain similar information more simply and perhaps more accurately by placing the patient on an x-ray table tilted so the lower extremities were dependent and injecting into the unobstructed vein. Furthermore, it occurred to me that if incompetency of the vein were demonstrated, good results might be obtained from vein ligation. I was unable to explore these possibilities, however, until after the war. Meanwhile in a second report Luke⁴ had stated that studies of twenty-nine venograms performed according to his original suggestion had demonstrated that passage of the dye beyond the first valve station down into the thigh did not necessarily indicate a malformed or diseased vein, though the retrograde opacification of the venous tree tended to be more extensive in patients believed to have incompetent femoral veins than in control subjects.

Since 1946 I have studied a number of patients by the method I outlined above. Though my experience is not large enough to permit me to be certain of the invariable accuracy of the method, thus far it seems to yield information which is of considerable value. After varying the technic in several ways, the following method was adopted. The patient is placed upon an x-ray table tilted about 45 degrees, with the feet down. The region over the femoral vein in the groin is infiltrated with 0.5 per cent procaine. A No. 18 or 19 needle is then introduced mesial to the femoral artery into the femoral vein. Approximately 25 cc. of 35 per cent Diodrast or 50 per cent Neo-iopax is then injected in a leisurely manner. As the injection is completed a film previously placed under the thigh is exposed by ordinary soft tissue technic. A film is next rapidly placed under the leg and exposed, and then a second roentgenogram of the thigh is made. Sometimes only two films are taken. In patients with apparently normal femoral valves the column of dye descends only to the first valve station just below the point of reception of the profunda, or, in some to the second valve station in the midthigh. A short segment of the femoral vein and usually of the profunda is visualized (Fig. 590, A). In patients with an incompetent femoral vein the dye descends down the thigh to the knee area or even into the leg (Fig. 590, B and

C). In many, but not all, there is some opacification of the profunda femoral as well. On occasions the incompetent valves are distinctly outlined by the contrast medium. The injection is ordinarily accom-

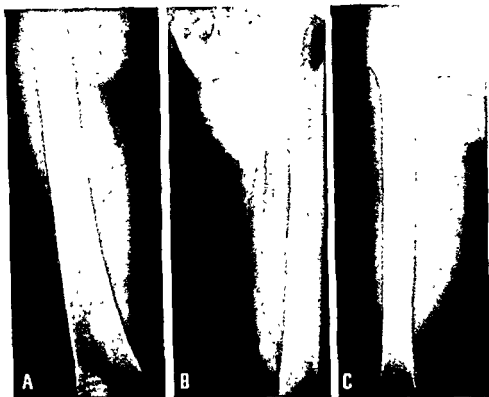


FIG. 590.—Retrograde venograms. *A*, Normal venogram in patient with leg ulcer of undetermined origin. It is seen that the femoral vein fills down to the first valve stations but no further. There is some reflux of the opaque medium into the profunda femoral vein.

B, Venogram performed upon a 66 year old man had had recurrent ulceration of leg for sixteen years. Varices had been treated by ligation and injection six years before. The venogram shows regurgitation of dye down the course of the femoral vein. The profunda is not visualized. Patient has done well following femoral and popliteal ligation and division and skin grafting but only a few months have elapsed since these procedures were carried out.

C, Venogram performed upon a 55 year old woman who had had recurrent ulceration of both legs over a five year period. Minimal varices were obliterated by injection. Venogram revealed the same disorder in both lower extremities. The dye is seen to regurgitate down the femoral and profunda femoral veins. A superficial femoral vein division has been performed upon one side and is to be carried out upon the other.

plished with little or no pain and is successful except in instances of thrombosis of the femoral vein in which a vena puncture cannot be performed.

Recently in a most interesting report Bauer⁵ has described his experiences with the same technic in patients with varicosities. He states the in almost every instance of chronic ulceration of the leg incompetency of the femoral vein has been demonstrated. He has treated these patients

with good results by popliteal vein ligation. I have by no means found all patients with leg ulcers to have incompetent femoral veins. A number of cases have shown such a disorder but in a number of others the study has revealed competency of the valves. In one patient in whom there was nothing to suggest a previous thrombosis the femoral vein was found to be incompetent and upon exploration the wall of the femoral vein was thickened but not thrombosed while the popliteal vein was occluded with an old thrombus (Fig. 590, B). In addition, in a number of patients without ulceration but with symptoms suggesting chronic venous stasis it has been possible to demonstrate incompetency of the femoral vein, ligation of which has produced remarkable alleviation of complaints. For example, one patient treated by my associate, J. S. Battersby, a young adult male athlete, who was incapacitated by fatigue and aching of his lower extremities on long standing and who had no swelling or cyanosis, was able to return to professional baseball shortly after bilateral superficial vein ligation and division. His symptoms were almost entirely relieved and he has had no edema.

Not every patient with unexplained symptoms and signs of venous stasis, however, will prove to have incompetency of the deep venous circulation. Patients with compatible symptoms or signs in whom it was demonstrated that the valves of the femoral vein were not competent have been treated either by ligation and division of the superficial femoral vein alone or by ligation and division of the popliteal vein as well. Other ancillary measures such as skin grafting were carried out as indicated. Thus far the results are most encouraging. Obviously, more extensive observations will have to be made both with the diagnostic procedure and with the therapeutic measures in order fully to evaluate this matter. The clinical significance of demonstrable regurgitation obviously requires intensive study. It is undoubtedly true that a considerable number of individuals without signs or symptoms of disordered venous return show regurgitation by the method used, just as was true in Luke's experience with his somewhat different technic. At the moment it appears that some individuals with incompetent femoral veins are without symptoms, just as some with incompetent saphenous veins are unaware of their presence. J. A. Campbell and I and our associates are currently trying to enlarge our experience in normal subjects as well as in suitable patients with symptoms suggestive of femoral incompetency in order to determine better the incidence of regurgitation in both groups. We shall also attempt to determine any influence of muscular activity upon such regurgitation. Though much remains to be clarified, it is believed that such studies add considerably to our ability to recognize and bring about reversal of some of the functional effects of disordered veins.

Stage Excision of Fluid-Accumulating Tissues in Chronic Lymphedema.—A further example of the fact that better treatment will result whenever there is a clear understanding of the physiopathologic nature of any given disorder may be exemplified by experiences with chronic

lymphedema. As long as there was alive the question of intact deep lymphatics and malfunctioning superficial lymphatics in cases of elephantiasis, it was natural that efforts at treatment should have been directed toward the creation of a functioning union between the two systems. Once Homans and his associates had produced chronic lymphedema experimentally for the first time and had demonstrated that it could only be produced by technics which apparently obliterated all, or nearly all, of the lymphatics to the limb, once they pointed out that in clinical cases of elephantiasis all, or nearly all, of the lymphatics are nonfunctioning, and once they were able to explain the absence of edema in the muscles on the basis of absence of lymphatics in normal muscle tissue, the type of treatment applicable was evident and rational even though not perfect. The excision in stages of those tissues which tend to accumulate lymph fluid, namely, those between the skin on the one hand and the deeper structures such as muscle, bone and tendon on the other, enables one to bring about remarkable reduction in swelling, abolition or marked decrease in number of attacks of elephantiasic fever, and useful function of limb. Though one might desire a more physiological method of treatment, I know of no more grateful patients than those who have been handled according to Homans' suggestion. Until there should become available a new method which would permit reintroduction of functioning lymphatic vessels in the limb, the present method of treatment appears to be the soundest in principle and to offer most relief to the elephantiasic patient.

Instruments.—It is fortunate that for all practical purposes no special instruments are required for the diagnosis and treatment of the vast majority of the peripheral vascular disorders. All that is generally necessary is proper fundamental training of the physician, proper use of his sense of touch and vision, and such apparatus as is available to all practitioners—a stethoscope, a syphgmomanometer, needles and syringe. Obviously for more detailed investigative study all the instruments, simple or intricate, which yield some information about the circulation are of extreme usefulness. Indeed with all those available there is still need for more. It would be safe to predict that each new instrument which permits a more accurate interpretation to the total circulation or of any of its component parts will result in new knowledge of the physiology of peripheral vascular disorders and may lead to more physiological methods of treatment.

Management of the Ischemic Limb.—We must keep constantly in mind the many basic problems which need to be clarified. In a sense it is discouraging how little exact knowledge we have concerning some of the most fundamental importance. Perhaps the commonest and most urgent problem in the entire field has to do with the management of the ischemic limb. It would appear reasonable that two methods might be of benefit in such cases: first, and the preferable one, to improve the blood flow to the part without proportionately increasing the metabolic needs, and second, to decrease the metabolic requirements without

decreasing proportionately the arterial inflow into the extremity. Thus far inferences concerning such proportionate alterations are based only upon speculation or upon clinical impressions.

Since such measures as sympathetic denervation are generally beneficial we assume that they do not increase local metabolism as much as they increase blood flow. There is much to suggest, on the other hand, that the local application of heat is apt to increase the metabolic needs out of proportion to the resultant improvement in circulation; such conclusions are based upon numerous cases of gangrene or extension of existent gangrene following utilization of this method. The use of local refrigeration was based upon the assumption that a striking reduction of metabolic processes resulted from chilling the limb. We know, however, that local cooling also diminishes blood flow; whether this reduction in blood flow is proportionately greater or less than the decrease in metabolic needs is unknown.

For these reasons, most of us attempt to increase blood flow by sympathetic interruption, indirect reflex vasodilatation, or some similar method. We avoid the use of local heat to the ischemic limb and we restrict the use of local refrigeration to those extremities in which the hopelessness of the situation is apparent and in which a decision to perform a major amputation has already been made. Obviously some day we must know, if it is at all possible, the precise relationship between increase or decrease in blood flow and simultaneous increase or decrease in metabolic tissue requirements resulting from each method of potential usefulness. The solution of such problems as these will undoubtedly permit a better physiological approach to the treatment of the peripheral vascular disorders.

SUMMARY

In this discussion I have attempted to illustrate the application of surgical methods which permit some functional rehabilitation of the limb with disordered circulation. In some instances one can effect perfect physiologic restitution, in others the results are only fair and in still others poor. In some a direct attack is possible. In others one must utilize very indirect means in attempting to correct the altered function. I have also attempted to stress the importance of fundamental knowledge concerning the etiology, the pathogenesis, and the physiological derangement resulting from the circulatory disturbance, as well as the importance of early recognition, precise localization, and prompt and adequate treatment. In spite of the handicaps under which one works and in spite of the tragic situations in which loss of limb and function prevail, the over-all picture permits a certain amount of satisfaction and optimism. If the means of diagnosis, study and treatment currently available are used wisely, a reasonably good job can be done. If, in addition, the basic problems which block the way are constantly recognized and every effort is made to solve them, it is certain that some

day the outlook for those suffering from these difficulties will be much brighter.

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THE SURGICAL PHYSIOLOGY OF HYPERTENSION

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INTRODUCTION

The most prevalent forms of hypertension are those commonly designated as essential and malignant. While the cause is unknown, many theories have evolved since the days of Richard Bright¹ to whom must go the credit for clarifying the relationship between diseased kidneys and hypertrophied hearts. At that time the emphasis was upon kidney disease as the primary event. As time has gone on, and with the development of a method for measuring blood pressure at the turn of the last century, it has become generally recognized that hypertension commonly exists without clinical evidence of renal damage as measured by ordinary tests of renal function. Emphasis gradually shifted away from kidney disease as the usual cause and in fact, largely as the result of the brilliant studies of Gull and Sutton in 1872,² the concept that hypertension was due to a primary disease of the arterioles in which the kidneys might or might not participate came into being before the introduction of the sphygmomanometer.

The ability to measure blood pressure together with the introduction of the ophthalmoscope, the x-ray, the electrocardiograph and kidney function tests made it possible to correlate evidence of vascular disease with hypertension. As a consequence it became gradually recognized that in the early stages of this disorder evidence of vascular disease was usually lacking. This, together with the surprising variability of blood pressure of most patients and evidence of hyperreactivity of smooth muscle to many stimuli such as cold, pain, emotion and change of posture indicated that, in the beginning hypertension was due to altered physiology of smooth muscle. The failure to demonstrate increased blood volume, viscosity, or cardiac output led to the general belief that elevated blood pressure was caused by increased peripheral resistance due to widespread constriction of the arterioles. Because vasoconstrictor fibers reach the blood vessels by way of the sympathetic nervous system, it seemed probable that this division of the autonomic nervous system was implicated in the mechanism responsible for increased peripheral resistance to blood flow.

As a result of the experimental work of Goldblatt,³ commencing in 1934, emphasis again shifted to the kidney. His presumption that primary disease of the renal arterioles and a consequent reduction in blood flow through the kidney resulted in the elaboration of a pressor

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(vasoconstrictor) substance and hypertension appeared to be substantiated by the production of hypertension in dogs by partial occlusion of arteries. Forms of hypertension were produced which resembled hypertension in man. However, a study of biopsies of eyes of hypertensive man failed to substantiate the premise that arteriolar sclerosis was the primary event, for in the early stages of hypertension renal vascular disease of consequence was rarely present and in longstanding hypertension about half of the cases did not have changes in the renal arterioles sufficient to be the sole initiating factor.⁴ Since at death, as shown by Moritz and Oldt,⁵ the vast majority of hypertensive patients do have marked renal arteriolar sclerosis, the probability that the vascular developed along with the hypertension or as a consequence of it seemed more likely.

Other evidence pointing to a physiologic rather than a pathologic mechanism as the primary event has resulted from the quantitative renal blood flow studies of Homer Smith⁷ and his associates. They likewise have reached the conclusion that altered renal blood flow is a secondary event. They felt, however, that this was due to a humoral rather than a neurogenic mechanism. The demonstration of pressor substances in the blood in response to renal ischemia under certain circumstances indicates that such a mechanism may play a role in the production of widespread vasoconstriction.

Experimentally, chronic neurogenic hypertension has been produced in animals by Heymans⁸ and others. Widespread vasoconstriction may be produced by sectioning the buffer nerves and denervating the carotid sinuses as well as in other ways. The observations of Trueta⁹ that the blood flow to the renal cortex may be reduced by the shunting of blood from the arteries to the veins in the medullary portion of the kidney indicates that it is not necessary to have pathologic renal arterioles in order to have reduced renal blood flow. It was also demonstrated that decreased renal blood flow could be produced by reflex stimulation of the sympathetic nervous system. The same undoubtedly applies to other viscera as well. Thus it is conceivable that in the early stages of hypertension, vasoconstriction due to nervous and humoral mechanisms may exist. The former might initiate the latter. Vascular disease appears to be a secondary event and when present undoubtedly further complicates the picture and may be an important factor in preventing the reversibility of the hypertensive mechanism. More recently Selye¹⁰ and Heinbecker¹¹ have emphasized the possible role of the adrenal medulla, the pituitary and the adrenal cortex in the production of hypertension. It is thus apparent that we are dealing with a complicated disorder the cause of which is not known. It seems probable that neurogenic and humoral mechanisms are both implicated, and vascular disease as well.

DEVELOPMENT OF HYPERTENSION IN MAN

From the clinical viewpoint something is known about the natural history of this disorder; having in mind particularly the therapeutic approach to the problem, which is necessarily more or less empirical, it is well to consider the observed characteristics of this disorder. These may be summarized briefly. It seems highly probable that in the pre-hypertensive stage, the blood pressure is unusually variable within a normal range. At this time, the phenomenon of hyperreactivity as evidenced by an unusual blood pressure response to emotion or physical activity probably exists. Such individuals were classified as hyperreactors by Hines and Brown¹² who found that they responded to a one-minute period of immersion of one hand in ice water by a rise in blood pressure of more than 20/15 mm. of mercury. About 15 per cent of so-called normal people react in this fashion. If followed for long periods of time, such individuals appear to be much more likely to develop hypertension than those who do not hyperreact. There is evidence that this characteristic is inherited. Thus it seems apparent that a predisposition to the development of hypertension exists in many cases.

With the passage of time, probably many years as a rule, the blood pressure becomes intermittently elevated. Thus, when the patient is emotionally stimulated or is responding to physical activity, the physician finds the blood pressure elevated. At first, it may fall promptly to normal after a short rest period in the horizontal position. Under these circumstances the hypertension may be regarded as transient. Later it may require hours, days or weeks of rest for spontaneous reversal to take place. We have arbitrarily considered that if the diastolic level fails to fall to below 90 mm. after forty-eight hours of bed rest, the disorder has passed from the stage of intermittent or transient hypertension to the stage of persistent or continued hypertension.

It is of interest and of great clinical importance to be aware of the manner in which hypertension develops in man. This is so not only from the viewpoint of theories of origin but also from the viewpoint of prognosis. So long as hypertension is spontaneously reversible in response to short periods of rest, cardiovascular disease is rarely in evidence and the prognosis is excellent. Occasional male patients develop cardiovascular changes of consequence in the stage of transient hypertension. This is rarely the case in females. It is undoubtedly true that most hypertensive patients remain in the stage of intermittent hypertension for many years. Since most physicians do not differentiate between intermittent and persistent hypertension they may gather the impression that hypertension may be a relatively benign disorder.

In my experience, once patients have reached the stage of persistent hypertension, as we have defined it, evidence of cardiovascular damage varying from slight to marked is present in over 95 per cent of patients.

From this point on, the prognosis becomes quite different and varies according to the amount of cardiovascular damage which exists when the patient is first seen and the severity of the hypertension as judged by the resting diastolic blood pressure level. The prognosis for males is poorer than for females. Once hypertensive patients develop cardiovascular changes these changes are progressive in nature. The rate of progress of cardiovascular disease varies greatly. Once cardiovascular disease develops the prognosis must be guarded because few hypertensive patients live to die of causes other than those related to cardiovas-

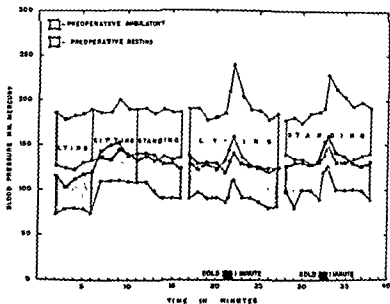


Fig 591—In this patient, the blood pressure levels were determined by means of the postural and cold test. This is described in detail in the section dealing with selection of patients for surgical treatment. In this case the test was performed first while the patient was ambulatory and again after a forty-eight hour period of bed rest. The blood pressure levels in the horizontal position fell to within the normal range after the short period of bed rest. This is an example of transient or intermittent hypertension.

cular disease. About 60 per cent die of cardiac complications, 20 per cent of cerebral accidents, 10 per cent of renal failure, and less than 10 per cent of unrelated causes. It is therefore apparent that when hypertension becomes persistent and cardiovascular disease begins to make its appearance the question of therapy should be considered. In the last analysis the merits of any form of therapy for this disorder will be judged by its effect upon the rate of progress of cardiovascular disease and upon life expectancy. The fact that the stage of persistent hypertension, with the rare exception referred to, is the beginning of the crucial phase of this disorder cannot be overemphasized. This cannot be detected by ambulatory blood pressure readings. The patient must be placed at

bed rest. As already indicated, we employ a period of forty-eight hours of bed rest to differentiate between persistent and transient hypertension. This is well illustrated by Figure 591. Evidence of cardiovascular disease is rarely present in the stage of intermittent or transient hypertension and rarely absent in the stage of persistent hypertension.

SURGICAL APPROACH TO HYPERTENSIVE CARDIOVASCULAR DISEASE

Since the first attempt to modify the course of hypertensive cardiovascular disease by sympathectomy was made in 1924 by Adson,¹³ various technics for denervation of large vascular areas have been devised. Interest in the approach to the problem coincided with the extension of surgery of the autonomic nervous system beyond limited procedures such as cervical sympathectomy and periarterial sympathectomy which had been in use prior to 1925. The high mortality rate among patients with hypertensive cardiovascular disease, particularly for so-called malignant hypertension, was responsible for the clinical investigation of the value of this form of therapy which has been in progress in a number of clinics during the past twenty-five years. We have been primarily concerned with the stage of persistent hypertension associated with cardiovascular disease varying from slight to marked. The problem has been to determine whether sympathectomy can modify the course of this disorder to a statistically significant degree and if so, in which cases operation is indicated and which surgical technics are most effective. The following discussion will summarize evidence bearing upon these questions. Brief mention will also be made of two other surgical measures, unilateral nephrectomy and the removal of pheochromocytomas. These two operations are applicable to less than 1 per cent of hypertensive patients.

VARIOUS TECHNIQUES FOR SYMPATHECTOMY AND SPLANCHNICECTOMY IN HYPERTENSIVE PATIENTS

Since 1924 various surgical technics have been employed, commencing with periarterial sympathectomy, then bilateral lumbar sympathectomy, and followed by laminectomy and extensive anterior root section. The first two were discarded because they were inadequate and the third because of the high morbidity and mortality. Following this, technics for performing subdiaphragmatic splanchnicectomy,¹⁴ supradiaphragmatic splanchnicectomy,¹⁵ lumbodorsal or thoracolumbar splanchnicectomy,¹⁶ total thoracic sympathectomy and splanchnicectomy, and total sympathectomy¹⁷ were devised in that chronological order. These are diagrammatically represented by Figure 592. The supradiaphragmatic and the lumbodorsal or thoracolumbar technics have been employed most extensively. To date, however, only two reports dealing with the results of operations in sizeable numbers of cases followed for five years or more have appeared in the literature. The first was by Peet and Isberg¹⁸ dealing with the supradiaphragmatic procedure, and the second

bar splanchnicectomy.
 etably ten years is needed to establish
 measure upon the course of this disorder, subsequent
 this aspect of the problem will be confined to the data of these two authors

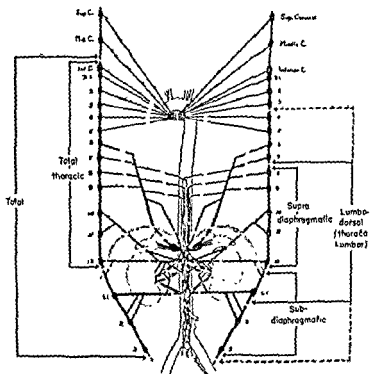


Fig. 592.—Technics for subdiaphragmatic, supradiaphragmatic and lumbodorsal (thoracolumbar) splanchnicectomy are illustrated in a diagrammatic fashion on the right side of this figure. Total thoracic and total sympathectomy are illustrated on the left. All operations are, of course, performed bilaterally.

Having had experience with all of the five technics referred to in Figure 2, it seems best to summarize my present attitude toward each of them.

Subdiaphragmatic Splanchnicectomy.—It is my belief that the subdiaphragmatic technic is inadequate because it may fail to interrupt important pathways to the visceral vascular bed which may reach the latter through fibers arising above the diaphragm. It also does not appear to safeguard against regeneration as effectively as other maneuvers.

Supradiaphragmatic Splanchnicectomy.—The supradiaphragmatic technic has the same shortcomings, but to a lesser degree, and in addition does not provide for exploration of the adrenal glands or kidneys. Consequently, pathologic changes in those areas may be overlooked, par-

ticularly unsuspected pheochromocytomas. This defect is less important since the advent of adrenolytic drugs but still exists to some degree.

Lumbodorsal and Thoracolumbar Sympathectomy.—the lumbodorsal or thoracolumbar procedure appears to combine the advantages of both of these technics, and if performed through a *retropleural transdiaphragmatic retroperitoneal approach*, does not increase the morbidity or mortality. The *transthoracic transdiaphragmatic technics* for lumbodorsal splanchnicectomy appear to be less desirable since they increase the morbidity and mortality. The principal motive for the development of this exposure has been to increase the extent of the procedure in an upward direction with removal of the sympathetic trunks as high as the third or fourth thoracic ganglia. In my opinion it is most unlikely that this will prove worthwhile in the long run; in the great majority of cases removal of the sympathetic trunks bilaterally in two stages, from the eighth thoracic to the first lumbar ganglia inclusive, together with the splanchnic nerves arising from this segment of the sympathetic trunk, is adequate. The operations are usually spaced ten days apart.

A more extensive removal of the lumbar chain results in a more marked postural hypotension and tachycardia postoperatively and greatly prolongs the period of convalescence. Removal of the second and third lumbar ganglia seems to be indicated only in patients who have an unusual degree of postural hypertension not associated with postural tachycardia.

Contraindications.—The lumbodorsal or thoracolumbar technic appears to be contraindicated in patients who have postural tachycardia as evidenced by a rise in pulse rate of 20 beats per minute or more in the upright as compared with the horizontal position as determined by the postural and cold blood pressure test. There are probably other forms of tachycardia in hypertensive patients which contraindicate lumbodorsal splanchnicectomy, especially those patients having rapid basal rates (100 per minute or more) associated with either postural tachycardia or an abnormal accelerator response to exercise as judged by the Masters' step test (a maximal response one minute after exercise of 150 per minute or more). In patients with these forms of tachycardia we have found that this abnormality may be intensified to a disabling degree following lumbodorsal splanchnicectomy and have gradually reached the conclusion that under these circumstances a transthoracic sympathectomy and splanchnicectomy is preferable. For the past few years, in these cases we have removed the sympathetic trunks and splanchnic nerves in two stages about two weeks apart, from the second to the twelfth thoracic ganglia inclusive. This maneuver includes the cardio-accelerator fibers since none appear to arise above the second thoracic level.

Additional contraindications to lumbodorsal splanchnicectomy appear to be coronary heart disease with definite angia pectoris which may be intensified unless the heart is included in the denervated area. Also, positive step tests as judged by abnormalities in the electrocardiogram following

exercise, at times associated with either unusual tachycardia or angina, may likewise prove to be an indication for thoracic sympathectomy. In such patients, particularly the group with coronary heart disease and angina pectoris, we feel at the present time that removal of the sympathetic trunks from the inferior cervical to the twelfth thoracic ganglia inclusive is the procedure of choice. A typical case in which both tachycardia and coronary heart disease with angina pectoris indicated the advisability of total thoracic sympathectomy and splanchnicectomy is illustrated by Figure 593.

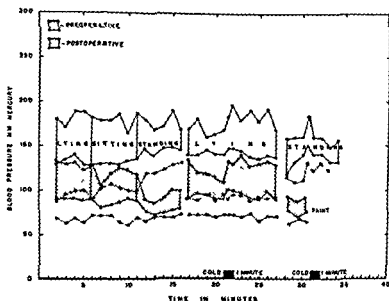


Fig 593.—In this figure, the postural and cold blood pressure tests and pulse rates are compared before and sixteen days after (shaded graph) total thoracic sympathectomy. This patient had angina pectoris and postural tachycardia before operation. In the acutely denervated state the blood pressure levels were lower, there was moderately severe postural hypotension with a slow pulse rate without postural acceleration.

Total Sympathectomy.—Over the years I have had occasion to extend thoracolumbar splanchnicectomy to total sympathectomy in sixteen cases for one reason or another. The indications were excessive and disabling tachycardia or the development of angina pectoris following lumbodorsal splanchnicectomy or the failure of the latter to influence basal blood pressure levels. I have not been impressed during this limited experience with the advantages of total sympathectomy other than to correct tachycardia or relieve angina pectoris. The great majority of these complications could have been avoided had a subtotal or total thoracic sympathectomy been performed in the first place. Total sympathectomy by inactivating both splanchnic vasoconstrictor and cardio-accelerator mechanisms has resulted in prolonged and total disability in

four of the sixteen cases due to inability to assume the upright position because of severe and persistent postural hypotension. This is well illustrated by Figure 594.

Summary.—In summary then, it is my belief that it is possible to do too little and also too much to hypertensive patients. If an adequate lumbodorsal splanchnicectomy or a subtotal or total thoracic sympathectomy is performed for the physiologic reasons outlined, the maximal benefit with minimal untoward physiologic effects will ensure. We find lumbodorsal splanchnicectomy to be indicated in about 85 per cent and subtotal or total thoracic sympathectomy in about 15 per cent of cases. It is my opinion that total sympathectomy is not indicated as a primary

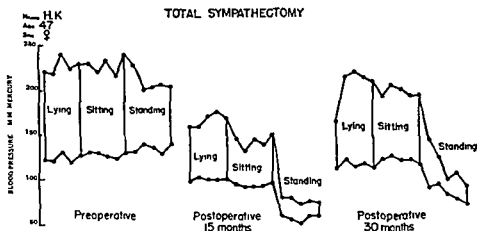


Fig. 594.—In this totally sympathectomized patient, postural hypotension continues to persist to a disabling degree thirty months after operation. The patient was unable to stand for five minutes without fainting for over a year after operation. Her activities are still greatly limited in spite of elastic stockings and a snug abdominal girdle. This has been an extremely trying experience for the patient, her family and the doctors concerned.

maneuver and probably rarely if ever indicated under any circumstances except perhaps to correct untoward physiologic effects resulting from the improper selection of the original procedure.

PHYSIOLOGIC EFFECTS OF ADEQUATE BUT NOT EXCESSIVE SYMPATHECTOMY AND SPLANCHNICECTOMY IN HYPERTENSIVE PATIENTS

If the operation is wisely selected for the particular patient, the favorable effects will greatly outweigh the unfavorable sequelae. The period of hospitalization will be reasonable (one month) and the period of early convalescence to the time patients begin to resume their previous activities will not be unnecessarily protracted (two months). With regard to the therapeutic value of sympathectomy and splanchnicectomy it seems certain that this is the result of a combination of favor-

able physiologic effects. These may be divided into *known and presumed* effects as indicated by Table 1.

Abolition of Sudden Elevations of Blood pressure Following Stimuli Which Result in Widespread Vasoconstriction.—This physiologic effect (Table 1) has been described by Wilkins *et al*.²⁰ These workers have shown that, following adequate thoracolumbar splanchnicectomy such as the bilateral excision of the sympathetic trunks from the eighth thoracic to the first lumbar ganglia inclusive, together with the splanchnic nerves arising from those segments, reflex elevation of blood pressure due to vasoconstriction is abolished or greatly reduced. The same effect is noted after total or subtotal thoracic sympathectomy in which the chains are removed from the inferior cervical or second thoracic to the twelfth thoracic ganglia inclusive. These two operative procedures are physiologically equivalent in this respect.

It is believed that the abolition of these sharp overshoots of blood pressure should greatly lessen the mechanical stress and strain on the cardiovascular system and may be an important factor in slowing the

TABLE 1

PHYSIOLOGICAL EFFECTS OF SYMPATHECTOMY AND SPANCHNICECTOMY

1. Known
 - a. Modification of reflex vasoconstrictor control of blood pressure
 - b. Lowering of basal blood pressure levels
2. Presumed
 - a. Inhibition of reflex secretion of epinephrine
 - b. Stabilization of blood flow through denervated viscera

progress of or reversing the severity of cardiovascular disease, and in increasing life expectancy. This favorable effect occurs in all patients subjected to these operations and appears to last for many years. It is independent of any change in basal blood pressure levels and has to do only with superimposed sudden elevations of pressure above basal levels.

This physiologic effect is well illustrated by Figure 593 in which the blood pressure responses to the Valsalva maneuver before and after splanchnicectomy are illustrated. The physiologic effect of total sympathectomy is no greater in this respect than that following lumbodorsal or total or subtotal thoracic sympathectomy as described. These reflex responses may be lessened somewhat after subdiaphragmatic or supradiaphragmatic splanchnicectomy but may still be very active; so far they have never been found to be abolished by either of these procedures.

Lowering of Basal Blood Pressure Levels.—This varies considerably from patient to patient, both in magnitude and duration. Most discussions of the value of surgery in the treatment of hypertensive cardiovascular disease have revolved about its effect upon blood pressure levels. It is now apparent that patients may be improved for years from the viewpoint of the cardiovascular system and relief of symptoms, and may also have their life expectancy increased significantly when the

effect of operation upon blood pressure levels is significant but temporary, or in other cases in which the basal levels are never significantly lowered.

Actually, lowering of blood pressure to a significant degree lasting for one to five years has been noted in about sixty per cent of completely unselected patients treated by lumbodorsal splanchnicectomy. With the passage of time there is a tendency for the levels to return toward pre-operative values so that about one-half as many patients continue to

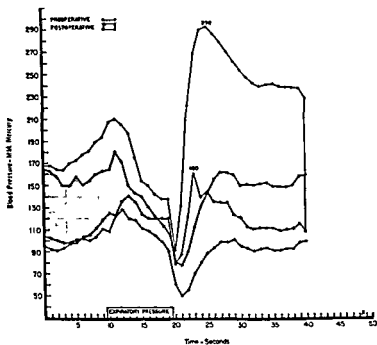


Fig. 595.—The Valsalva maneuver was performed before and after (shaded graph) lumbodorsal splanchnicectomy. The blood pressure levels are comparable in both tests before and during the ten second period of expiration against a pressure of about 40 mm. of mercury. In the latter portion of the test, widespread vasoconstriction results in a striking rise in blood pressure to 292/160 a few seconds after the expiratory phase before operation. After operation, this phenomenon is abolished. It is felt that this physiologic effect upon blood pressure, which occurs in all thoroughly denervated patients, is an important factor in reducing the stress and strain upon the cardiovascular system. This effect is not related to changes in basal blood pressure levels.

maintain lower levels during the second as during the first five-year period of observation. This respite, together with the abolition of reflex elevations of blood pressure which seem to persist even if the basal levels return to or toward the preoperative levels, appears to be sufficient to exert a very significant effect upon the progress of disorder.

An example of a marked and persistent effect upon blood pressure is illustrated by Figure 593, and of a slight but significant and temporary response by Figure 597; an insignificant blood pressure response associated with prolonged improvement of the cardiovascular system and symptomatic relief with unquestioned prolongation of life and economic

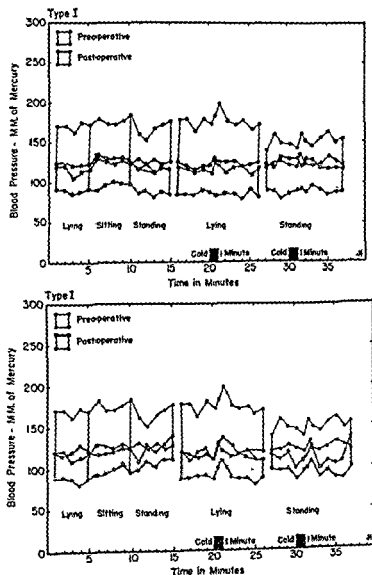


Fig. 596—In the upper portion of this figure the blood pressure levels, as judged by the postural and cold test, are compared before and twenty-nine months after (shaded graph) lumbodorsal splanchnicectomy. In the lower portion of the figure the levels are compared before and sixty-one months after operation. This is regarded as a significant and prolonged reduction in blood pressure levels. The patient was a 34 year old nurse, with incapacitating symptoms, grade 1 eyeground changes, an enlarged heart and an abnormal electrocardiogram. Otherwise there were no cardiovascular abnormalities of consequence. The patient is working steadily, is asymptomatic, has a normal electrocardiogram and heart size seven years after operation. The blood pressure levels remain status quo. Preoperatively, this patient was classified in our Group 1 (numerical grade 2, See Table 11 and Fig. 601 for mortality and survival rates for comparable patients).

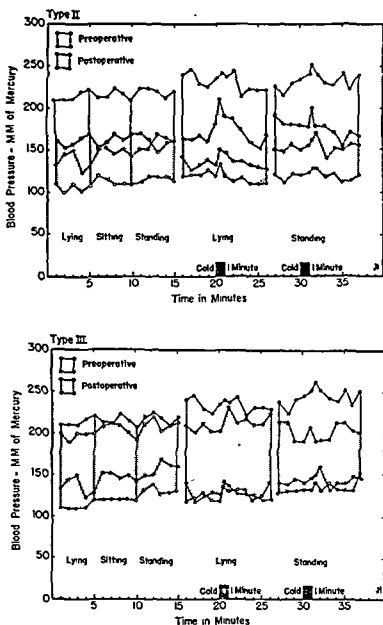


Fig 597.—In the upper portion of this figure the blood pressure levels, as judged by the postural and cold test, are compared before and sixteen months after (shaded graph) lumbodorsal splanchnicectomy. In the lower portion, the levels are compared before and 60 months after operation. This is regarded as a slight but significant and temporary reduction in blood pressure levels. The patient was a 43 year old woman, with incapacitating symptoms, grade 3 eyeground changes and an abnormal electrocardiogram. This patient is living and well and relatively asymptomatic six and one-half years after operation. Her eyegrounds are grade 2, her electrocardiogram is normal. There has been no progression of cardiovascular disease in any 2 (numerical grade 1; see Table 11 and F for comparable cases) This case was seen following a temporary reduction in blood pressure levels. It emphasizes the fact that the beneficial effects of splanchnicectomy are not due solely to the effect upon blood pressure levels.

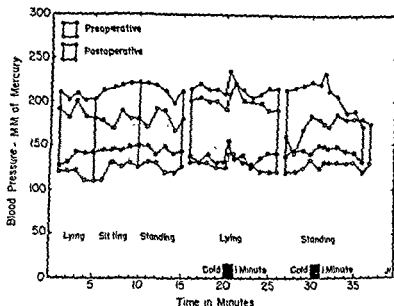
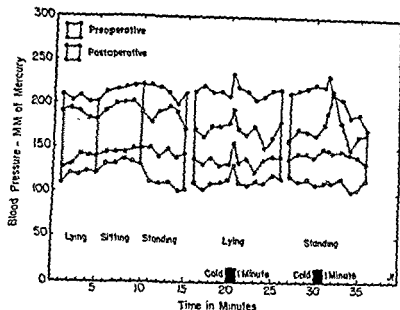


Fig 593 —In the upper portion of this figure the blood pressure levels are compared before and twenty-four months after operation. In the lower portion, the levels before and sixty months after operation are compared. At no time was the effect of operation upon blood pressure levels regarded as significant. The patient was a 51 year old male with rapidly progressing hypertension of the so-called malignant variety, with grade 4 eyegrounds, an enlarged heart and an abnormal electrocardiogram. At the present time, six years after operation, the patient is living and well, working hard, and asymptomatic. There has been no progression of cardiovascular disease. The eyegrounds are graded 2, the electrocardiogram is improved but abnormal, and the heart size is normal. This case likewise illustrates the fact that beneficial results are not dependent solely upon the effect of operation upon pressure blood levels. This case likewise falls into our Group 2 (numerical grade 3, see Table 11 and Fig. 601 for mortality and survival rates for comparable cases).

rehabilitation is illustrated by Figure 598. Significant and prolonged reduction of blood pressure levels is illustrated by Figure 599.

Abolition of Reflex Secretion of Epinephrine.—In addition to the known effects it may be safely presumed that reflex secretion of epinephrine is abolished. This might both directly and indirectly, through the adrenal cortex, exert a favorable effect upon the hypertensive state. Stabilization of blood flow through the viscera with a decrease in the periods of reduced blood flow due to vasoconstriction probably also results from splanchnicectomy. This might exert a favorable influence upon the elaboration of pressor substances by viscera in response to periods of ischemia if such a mechanism actually exists in man. It seems probable that the favorable effect of splanchnicectomy upon the course of hypertensive cardiovascular disease is the result of a combination of the physiologic effects of the procedure upon the cardiovascular system.

Untoward Effects.—Certain untoward effects are also noted but, as has been previously pointed out, these are greatly outweighed by the favorable effects if the proper operation is selected for the particular case. Among the unfavorable effects are moderate postural hypotension and tachycardia, excessive perspiration in hot weather and cooling of undenervated areas in cold weather. If loss of ejaculation is to be avoided in a given case, the lumbar outflow should be preserved on one side. Impotence is very rare and may be disregarded. There is no good physiologic explanation for this as this function is mediated by the parasympathetic division of the autonomic nervous system.

Eighty-three per cent of the patients we have interviewed five to ten years after operation state that the untoward physiologic effects of operation are more than counterbalanced by the favorable effects. The one most troublesome problem continues to be a variable degree of post-operative intercostal neuritis. This persists for a number of weeks in most cases, is rarely absent, and occasionally is very severe. It may last for several months. With increasing experience and facility in performing the operations this problem becomes less troublesome. However, I suspect that the combination of sympathectomy and irritation of peripheral nerves results in the elaboration of substances which are irritating to somatic nerve endings and causes this particular type of neuralgia. In severe cases, peripheral nerve block or subcutaneous procaine infiltration is helpful temporarily, as is also moist heat.

COMPARISON OF MORTALITY AND SURVIVAL RATES FOR SURGICALLY AND NONSURGICALLY TREATED HYPERTENSIVE PATIENTS

A comparison of mortality and survival rates for surgically and non-surgically treated hypertensive patients indicates that the prognosis has been significantly improved following lumbodorsal splanchnicectomy. Mortality rates for representative series of nonsurgically treated patients followed for five to ten years are summarized in Table 2.²¹⁻²⁶ It will be noted that the mortality varies widely in the different series from 28 per cent to 91 per cent. A study of these statistics indicates that

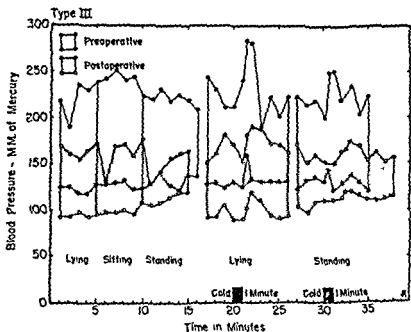
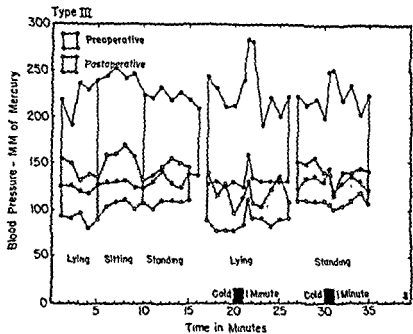


Fig. 599. In the upper portion of this figure the blood pressure levels are compared before and twelve months after operation. In the lower portion, the levels before and sixty months after operation are contrasted. This is a marked and persistent reduction in blood pressure. The patient was a 42 year old female, with

if the patients are divided according to sex, the mortality rate is almost twice as great for males as for females. This is indicated by Table 3.

TABLE 2
MORTALITY AMONG HYPERTENSIVE PATIENTS NOT TREATED SURGICALLY

Author	Number of Cases	Time Followed	Mortality
Janeway (1913)	244	5-10 years	81%
Blackford, Bowers and Baker (1930)	202	5-11 years	50%
Keith, Wagener and Barker (1939)	219	5-9 years	91%
Rasmussen and Boe (1945)	100	6 years (average)	52%
Bechgaard (1946)	1038	4-11 years	28%
Palmer, Loofbourow and Doering (1948)	430	8 years (average)	61%
Total	2233	Average	50%

TABLE 3
MORTALITY AMONG HYPERTENSIVE PATIENTS NOT TREATED SURGICALLY

Author	Males	Females
Janeway (1913)	86%	69%
Blackford, Bowers and Baker (1930)	70%	39%
Keith, Wagner and Barker (1939)	93%	88%
Rasmussen and Boe (1945)	71%	43%
Bechgaard (1946)	41%	22%
Palmer, Loofbourow and Doering (1948)	72%	52%
Average*	67%	37%

* Weighted according to number of cases making up each percentage.

TABLE 4
MORTALITY AMONG HYPERTENSIVE PATIENTS TREATED SURGICALLY

Author	Technic	No. of Cases	Time Followed	Mortality		
				Total	Males	Females
Peet and Isberg (1946)	Supradiaphragmatic splanchnicectomy	437	5-12 years	42 5%	62%	30%
Smithwick (1948)	Lumbodorsal (thoracolumbar) splanchnicectomy	326	5-10 years	29%	35%	24%

The mortality rates for the Peet and Isberg series and for the first 326 consecutive unselected hypertensive patients to be treated by lumbodorsal splanchnicectomy are summarized in Table 4. A study of the

Rasmussen and Boe series indicates that the mortality rate for non-surgically treated patients increases as the resting diastolic blood pressure level becomes more severe. This is indicated by Table 5 in which the mortality rates for our 326 surgically treated patients are included for comparison.

Among the control series referred to in Table 2, that of Keith, Wagener and Barker deserves particular mention since this represents the first attempt to divide hypertensive patients into more comparable groups on the basis of cardiovascular abnormalities. This series of 219 cases was divided into four groups largely on the basis of the changes noted in the eyegrounds. The patients in Group 1 had mild narrowing or sclerosis of the retinal arteries. Those in Group 2 had moderate to marked sclerosis of the retinal arteries characterized especially by exaggeration of the arterial reflex and arteriovenous compression. Group 3 contained patients

TABLE 5
MORTALITY AMONG HYPERTENSIVE PATIENTS 6 YEARS (AVERAGE) AFTER FIRST EXAMINATION OR 5-10 YEARS AFTER OPERATION

Resting Diastolic Level	Rasmussen and Boe			Smithwick		
	No of Cases	Deaths	Mortality	No of Cases	Deaths	Mortality
90-109	46	20	43%	83	7	8%
110-124	31	16	58%	108	25	23%
125+	19	14	74%	135	62	46%
Total	96	52	54%	326	94	29%

with angiospastic retinitis characterized especially by edema, cotton-wool exudate and hemorrhages in the retina superimposed upon a combination of sclerotic and spastic lesions in the arteries. If measurable edema of the optic disks was added to this picture the case was placed in Group 4.

We have divided 305 of our 326 cases followed for five to ten years after operation into comparable groups. The remaining twenty-one cases had normal eyegrounds and are not included since no patients with normal eyegrounds were referred to in the Keith, Wagener and Barker series. The mortality rates for the two series are compared in Table 6. It will be noted that there is a marked difference in all groups which is statistically significant for Groups 2, 3 and 4. There are too few cases in Group 1 in the control series to be of significance. Keith, Wagener and Barker also expressed the outlook for their patients by constructing survival curves for each group. We have made similar curves for our cases, and the curves for the two series are compared in Figure 600. The marked difference between the outlook for the surgical and the medical series is apparent. In commenting upon their patients,

TABLE 6

MORTALITY AMONG HYPERTENSIVE PATIENTS 5-9 YEARS AFTER FIRST EXAMINATION OR 5-10 YEARS AFTER OPERATION

Hypertension Group or Grade Eyegrounds	Keith, Wagener, Barker			Smithwick		
	No. of Cases	Deaths	Mortality	No. of Cases	Deaths	Mortality
N	—	—	—	21	1	5%
1	10	4	40%	88	10	11%
2	26	17	65%	90	21	23%
3	37	34	92%	84	40	48%
4	146	145	99%	43	22	51%
Total	219	200	91%	326	94	29%

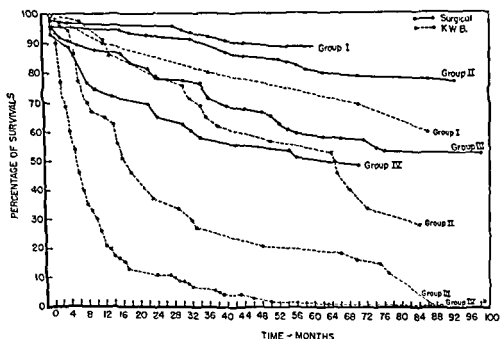


Fig. 600.—In this figure, the survival curves for our first 305 consecutive unselected patients.

The differences observed are statistically significant for groups 2, 3 and 4. The nonsurgical cases were followed five to nine years and the surgical five to ten years.

Keith, Wagener and Barker expressed the opinion that their data could serve as control material by which the merits of any particular form of therapy for hypertensive cardiovascular disease might be judged.

More recently, Palmer, Loofbourow and Doering presented follow-up data for medically treated patients followed for an average period of

eight years. These data are less satisfactory for purposes of comparison since an average follow-up period of observation is not so explicit and is consequently impossible to duplicate accurately. They divided their cases into four groups in which the most important changes in any one area determined the grade for the particular patient. They divided their patients into four grades as follows:

Grade 1. These patients have no changes or minimal changes in the fundi as represented by narrowing of the arterioles, normal hearts or no more than prominence of the left ventricle by x-ray study, no impairment of renal function by the tests used, and normal urine examination, or occasionally slight albuminuria and slight changes on microscopical examination of the sediment.

Grade 2. These cases include moderate organic changes in the fundi as represented by widening of the arteriolar light reflex, narrowing, caliber changes and arteriovenous compression. The heart rarely is normal by x-ray study; it is usually prominent in the region of the left ventricle and sometimes more definitely enlarged but without functional impairment; the kidney is normal, slight degrees of albumin and minimal numbers of formed elements are found in the urinary sediment, or there may be slightly impaired function.

Grade 3. The fundi are rarely normal, usually showing arteriolar narrowing, caliber changes, wide light reflex and arteriovenous compression. Often there are exudates and hemorrhages; the heart is often moderately to markedly enlarged, commonly with symptoms and signs of actual or impending congestive failure or symptoms of anginal failure. The urine frequently shows albuminuria and casts, and renal function is often impaired though actual failure (uremia) is not common, cerebral accidents occur in about 20 per cent of cases.

Grade 4. The cardinal—indeed, the obligatory—sign is edema of the optic disks, with or without exudates and hemorrhages and always with marked narrowing of the arterioles. Cardiac enlargement and congestive failure may be present; renal impairment and failure are common.

We have arranged our 326 cases followed five to ten years into similar grades and the mortality rates are compared in Table 7. The difference between the two series is marked and statistically significant for all four grades. This also would appear to indicate a conclusion that the

two series. The mortality rates in both the Keith, Wagener and Barker and the Palmer, Loofbourow and Doering series are very high and indicate that the prognosis for patients with persistent hypertension and cardiovascular disease is poor. The division of hypertensive patients into four groups as suggested by these authors is helpful since it makes a comparison of two different series of cases more accurate. However, since the method for grouping or grading employed by these authors is such that the classification of a given case is determined by the changes in a single vascular area, it is possible that the patient material contained

within each of the four groups or grades as defined will vary greatly. In order to circumvent this difficulty we have devised a plan for arranging patients into five groups. In defining each group, many variable factors which influence prognosis are carefully controlled. There is no doubt which group a given patient belongs in. This should give greater assurance that the patients in each group will be comparable, and facilitates the discussion of the selection of cases for surgical treatment.

TABLE 7
MORTALITY AMONG HYPERTENSIVE PATIENTS 8 YEARS (AVERAGE) AFTER FIRST EXAMINATION OR 5-10 YEARS AFTER OPERATION

Grade of Hypertension	Palmer, Loofbourow, Doering			Smithwick		
	No. of Cases	Deaths	Mortality	No. of Cases	Deaths	Mortality
1	104	23	22%	36	2	6%
2	80	38	47%	80	8	10%
3	192	150	78%	167	62	37%
4	54	51	94%	43	22	51%
Total	430*	262	61%	326†	94	29%

* 66.5 per cent of total material.

† 98 per cent of total material.

SELECTION OF PATIENTS FOR SURGICAL TREATMENT

Method of Study.—An outline of the method of study used is given because the data serve as a basis for dividing cases into a number of groups. If this information is available, it is then possible to judge the prognosis for a given patients with considerable accuracy. In general, patients who fall into Groups 1, 2, or 3 are regarded as suitable cases for surgery. With few exceptions those who fall into Groups 4 and 5 are poor candidates for surgical treatment. By comparison with control data in the literature, concerning nonsurgically treated patients, the life expectancy following splanchnicectomy appears to have been increased to a statistically significant degree in cases falling into Groups 1, 2, and 3. This is not the case for patients falling into Groups 4 and 5.

In addition to a detailed history and physical examination the following information is desirable:

Examination of Eyegrounds.—The eyegrounds should be examined by an ophthalmologist, with fully dilated pupils. Occasional patients with continued hypertension have normal eyegrounds. A simple classification has been used which divides the abnormal cases into four grades. (1) Into this grade are placed cases with spasm only, generalized narrowing or irregular constrictions, or both, of any degree, without evidence of sclerosis, and without hemorrhage, exudate or papilledema. (2) Sclerotic changes, particularly arteriovenous compression, generally associated

and/or exudate but without papilledema, regardless of the changes in the vessels (4) *Papilledema*, measurable elevation of the disk, is the principal criterion for inclusion in this group. It is generally associated with hemorrhage and exudate and changes of consequence in the retinal arteries.

Determination of Cardiac and Renal Status.—The cardiac status is determined by a cardiologist, supplemented by an electrocardiogram and a seven-foot heart plate with particular reference to the size and shape of the heart and the state of the aorta. The renal area is evaluated by urinalyses, a twelve-hour concentration test, an intravenous phenolsulfonphthalein test, the dye being injected after a period of forced fluid intake, and specimens collected at intervals of fifteen and thirty minutes and one and two hours. This ordinary test of renal function is useful in estimating the extent of renal damage in hypertensive patients and is the one we have come to rely upon most. A nonprotein nitrogen determination is made and intravenous pyelograms are obtained routinely.

Blood Studies—Blood studies include counts, smears, hemoglobin determinations, blood grouping, Rh factors, Hinton, blood sugar, serum protein, cholesterol and chlorides.

Neurologic Investigation—If a cerebral vascular accident has occurred a neurologic consultation is requested and such additional studies as skull plates, electroencephalograms and lumbar puncture are carried out as seem indicated.

Postural and Cold Blood Pressure Test—A postural and cold blood pressure test is performed as follows: the patient is required to have at least forty-eight hours of bed rest except for lavatory privileges. Following this preliminary period, the tests are carried out by technicians rather than physicians since the former are generally able to obtain lower readings than a physician, presumably because the latter often act as a pressor stimulus to the patient. Preliminary readings of blood pressure are taken on each arm. If no great discrepancy exists the right arm is used. If there is a marked difference on the two sides, this is checked a number of times and the arm with the higher reading is selected. The test is explained to the patient and after an additional rest period of fifteen to twenty minutes in the horizontal position observations are begun. It is essential that the environment be quiet, comfortable and pleasant. Ward patients are transported to a special room for performance of the test during which there should be no interruptions.

Reading of pulse and blood pressure are taken every minute for five minutes with the patient first lying, then sitting, then standing. The horizontal position is again assumed and five further readings at minute intervals are taken following which the opposite hand is immersed in ice water (4 to 5° C.) up to the wrist for exactly one minute, readings are taken after thirty seconds and at the end of the sixty seconds of stimu-

lation by cold. Readings are then continued at one-minute intervals for an additional five minutes. The patient then assumes the upright position and after five preliminary readings at one-minute intervals, the cold stimulus is repeated exactly as in the horizontal position. This is followed by five additional readings at one-minute intervals. The average of the first five readings in the horizontal position of the first portion of the postural and cold blood pressure test is regarded as the resting blood pressure level.

Sedative Test.—A sedative test is performed in all cases. Following a light supper, 3 grains of sodium amytal are given by mouth at 6:00, 7:00, and 8:00 P.M. Hourly readings of pulse and blood pressure are recorded from 7:00 P.M. to 7:00 A.M. The lowest reading of systolic and diastolic blood pressure is taken as the response. This is evaluated by

TABLE 8
METHOD USED FOR DETERMINING THE NUMERICAL
GRADE OF HYPERTENSIVE PATIENTS

Factors to Be Considered	Numerical Value of Each Factor
Cerebrovascular accident without or with residual	1
Abnormal EKG	
Enlarged heart	
Impending failure	
P.S.P. less than 25% in 15 minutes or 60% in 2 hours	
Age 50 or over	
Mild angina	2
Cerebrovascular accident with residual*	
Frank congestive failure moderate angina	
P.S.P. less than 20% in 15 minutes	
Unsatisfactory response to sedation	3
P.S.P. less than 15% in 15 minutes	
Nitrogen retention	4
* Cerebral deterioration or definite involvement of arm and/or leg	

comparison with the horizontal or resting blood pressure level as determined by the postural and cold test, and the diastolic response is regarded as the most significant figure. For patients with resting diastolic levels in the postural and cold test between 100 to 119 mm., the diastolic response to sedation should be 90 mm. or less, for those in the range of 120 to 129 mm., it should be 100 mm. or less, and for those with resting levels of 130 mm. or more it should be 110 mm. or less in order to be regarded as satisfactory. Better responses than this not infrequently occur and are regarded as good or excellent. Also, a lesser response is not uncommon and is regarded as poor.

Method Used to Determine the Numerical Grade of Hypertensive Patients.—To determine the numerical grade, the changes in the cerebral, cardiac and renal areas as well as the age of the patient and the response to sedation are first taken into consideration. The factors to be

considered and the numerical value of each is indicated in Table 8. Specific examples of the method of grading are given in Table 9. Patients who have a numerical grade of less than 4 will fall into either Group 1 or 2. Patients with a numerical grade of 4 or more will fall into Groups 3, 4, or 5. The striking difference in the mortality rates for patients with a numerical grade of less than 4 as compared with those having a numerical grade of 4 or more is indicated by Table 10.

TABLE 9

TWO EXAMPLES OF METHOD FOR DETERMINING NUMERICAL GRADE OF HYPERTENSIVE PATIENTS

Factors Considered	Numerical Value
Example 1	
Abnormal EKG	1
Cerebrovascular accident without residual	1
P S P 20% in 15 minutes	1
	—
Total	3 = Numerical grade
Example 2	
Abnormal EKG	1
Enlarged heart	1
P S P 10% in 15 minutes	3
	—
Total	5 = Numerical grade

TABLE 10

MORTALITY AMONG SURGICALLY TREATED HYPERTENSIVE PATIENTS FOLLOWED 5-10 YEARS ACCORDING TO NUMERICAL GRADING OF CARDIOVASCULAR STATUS

Numerical Grade	No. of Cases	Deaths	Mortality
Less than 4	255	31	12%
4 or more	126	78	62%
Total	381	109	29%

Method for Grouping Hypertensive Patients.—Having determined the numerical grade of a particular patient, one then proceeds to place the case into one of our five groups. If the numerical grade is less than 4 the case will fall into Group 1 and the changes in the cygrou with the mortality rates for each group. If the numerical grade is 4 or more the case will fall into Group 3, 4, or 5, depending upon the resting diastolic level and the severity of the cardiovascular changes in the cerebral, cardiac, or renal areas. This is indicated by Table 12 together with the mortality rates for these three groups. Survival curves have been plotted for the five groups and are illustrated by Figure 1. It is noted that the operative mortality is 1 to 22 per cent for Group 5.

In order to obtain some idea what the mortality rate for the patients in each of our five groups might have been had they been treated by conventional medical measures, the mortality rates for the patients in each group have been estimated by arranging the patients into the

TABLE 11

MORTALITY RATES FOR SURGICALLY TREATED HYPERTENSIVE PATIENTS FOLLOWED 5-10 YEARS; NUMERICAL GRADE LESS THAN 4

Group	Other Factors	No of Cases	Living	Dead	Mortality
1	Females and males with eyegrounds Grade 0 or 1 Females with eyegrounds Grade 2 or 4	175	162	13	7%
2	Females with eyegrounds Grade 3 Males with eyegrounds Grade 2, 3 or 4	80	62	18	23%

TABLE 12

MORTALITY RATES FOR SURGICALLY TREATED HYPERTENSIVE PATIENTS FOLLOWED 5-10 YEARS; NUMERICAL GRADE 4 OR MORE

Group	Other Factors	No of Cases	Living	Dead	Mortality
3	Resting diastolic level below 140 mm. Cerebrovascular accident with residual, or frank congestive failure, or P.S.P. below 15% in 15 minutes and poor response to sedation not present	52	38	14	27%
4	Same as 3 except that one or more of the cardiovascular changes re-referred to is present	38	7	31	82%
5	Resting diastolic level 140 mm. or more regardless of cardiovascular changes	36	3	33	92%

Keith, Wagener and Barker groups and the Palmer, Loofbourow and Doering grades. The observed and estimated mortality rates are summarized in Table 13. The actual mortality rates for patients in our first three groups are considerably lower than the estimated mortality rates, suggesting that surgical treatment is most effective in such cases. The actual and estimated mortality rates for patients in our Groups 4 and 5 are the same, suggesting that surgery has no influenced the prognosis in these patients.

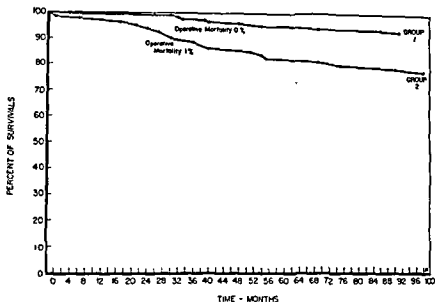


Fig 601.—Survival curves for surgically treated cases falling into our Groups 1 and 2, followed five to ten years, are illustrated. In all cases, the numerical grade was less than 4. The operative mortality in Group 1 was 0 per cent, while in Group 2 it was 1 per cent.

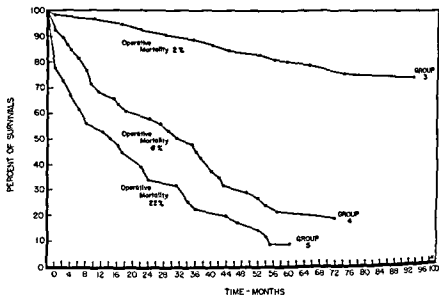


Fig 602.—Survival curves for surgically treated patients falling into our Groups 3, 4, and 5, followed five to ten years, are illustrated. In all cases, the numerical grade was less than 4.

Indications and Contraindications to Surgery.—Until further control data accumulate to serve as an additional check on these statistics, it would seem best to advise against operation in patients falling into our Groups 4 and 5. Operation may be recommended in patients falling into our Groups 2 and 3. With regard to our Group 1, it should be stated that this contains thirty-seven cases with minimal eyeground changes at

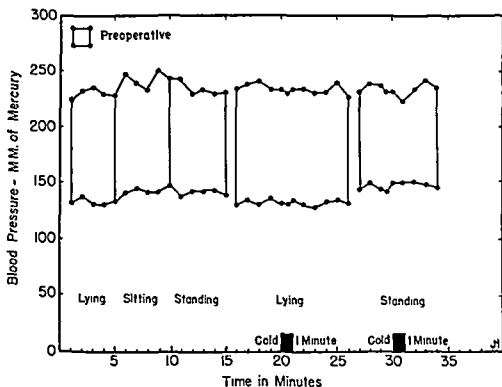


Fig. 603—Before operation this 39 year old woman had sustained a cerebral accident with definite residual paralysis. Her eyegrounds were grade 4. She had an enlarged heart, an abnormal electrocardiogram, frank congestive failure, marked reduction in renal function without nitrogen retention, and a poor response to sedation. Her numerical grade was 11. She falls into our Group 4. The patient died within a year after operation of a cerebral hemorrhage. This is a typical example of a case in which surgery is contraindicated. The mortality and survival rates for similar cases are given in Table 12 and Figure 602.

most, without demonstrable abnormalities in the cerebral, cardiac, or renal areas. These patients would fall into the Palmer, Loofbourow and Doering Group 1. The actual mortality rate for these patients was 5 per cent as compared with an expected mortality rate of about 20 per cent. It would seem permissible to observe such cases until further evidence of cardiovascular damage is apparent since the mortality rate in the remaining 138 cases in Group 1, who had more evidence of cardiovascular disease, was only 2 per cent higher. On the other hand, a longer period of observation may indicate that such a policy is undesirable. The other 138 cases in our Group 1 had either cerebral accidents, definite changes in the

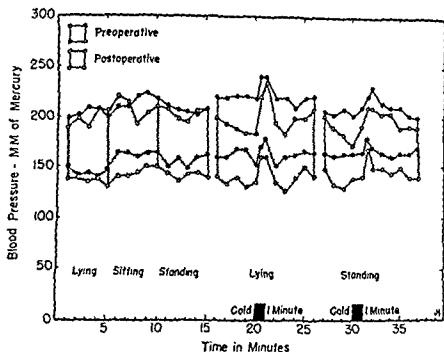


Fig 601.—In this figure, the blood pressure levels before and one year after

fulfillment of renal function as a result of nitrogen retention and a more response to

TABLE 13

MORTALITY RATES FOR SURGICALLY TREATED HYPERTENSIVE PATIENTS FOLLOWED 5-10 YEARS COMPARED WITH MORTALITY RATES ESTIMATED FROM THE KEITH, WAGENER AND BARKER, AND PALMER, LOOFBOUROW AND DOERING CONTROL DATA

Observed Mortality				Mortality Estimated From	
Group	No. of Cases	Deaths	Mortality	KWB Data	PLD Data
1	175	13	7%	54%	47%
2	80	18	23%	86%	84%
3	52	14	27%	73%	74%
4	38	31	82%	79%	82%
5	36	33	92%	91%	83%

cardiac area such as enlarged hearts or abnormal electrocardiograms or both, with early failure in some, or slight to moderate reduction in renal

function and in many females grade 2 or 4 eyegrounds. The actual mortality rate for these 138 cases was 7 per cent as compared with an estimated mortality rate of about 50 per cent. On the basis of the evidence at hand it would seem desirable to recommend surgery in these Group 1 patients.

It should be emphasized that the control data available have to do with the outlook for hypertensive patients treated by so-called conventional medical measures. It does not take into consideration the long range outlook for hypertensive patients treated by more recently developed diets and drugs. Whether these measures, such as severe and prolonged dietary restrictions, particularly of salt intake, will materially influence the long range prognosis will not be known for years. In the meantime it seems proper to recommend surgery where it appears to have been most effective. It also seems probable that the best results in the long run will be obtained by those patients who have the benefit of both surgery and medicine. It is becoming increasingly obvious that surgery should not be reserved as a last resort.

OTHER SURGICAL MEASURES IN TREATMENT OF HYPERTENSIVE CARDIOVASCULAR DISEASE

Unilateral Nephrectomy.—Brief mention should be made of unilateral nephrectomy in the treatment of hypertensive cardiovascular disease. Following Goldblatt's brilliant animal experiments, the possibility that a diseased kidney might elaborate a pressor substance and cause hypertension received widespread consideration. As a result, a considerable number of patients were treated by nephrectomy. A recent review of reported results by Homer Smith²⁷ reveals a number of cases in which the hypertension has been favorably modified without doubt. So far it has been impossible to predict which patients will respond. It is generally agreed that the indications for nephrectomy in hypertensive patients should be the same as for nonhypertensive patients. Only seriously damaged or nonfunctioning kidneys should be removed. The opposite kidney should be normal. It is inadvisable to remove the poorer of two involved kidneys.

Pheochromocytomas.—Hypertension due to a pheochromocytoma is rare. Since removal of such a tumor is almost always successful, it is important that this diagnosis be kept in mind as a possibility in every hypertensive patient. To date there are about 250 case reports in the literature. Only about one-third of the patients were operated upon. The tumors in the other cases were discovered at autopsy.

Most of these patients have a history of paroxysmal attacks of hypertension associated most commonly with headache, palpitation, vomiting and sweating. It is important to realize, however, that some patients do not have these attacks and may be regarded as having so-called essential hypertension. In such cases, unexplained temperature elevations, excessive sweating, a basal metabolic rate of plus 20 or more, elevated blood

sugar and rapid heart rate, particularly postural tachycardia associated with postural hypotension, should lead one to suspect the presence of a pheochromocytoma.

The introduction of adrenolytic drugs²⁸ has helped to confirm the presence of a pheochromocytoma and is a much safer procedure than the precipitation of an attack with histamine or mechohyl. The use of the latter drugs is questionable in patients with high sustained types of hypertension. An adrenolytic blocking agent should be available to stop the attack if precipitated in such cases

These tumors are small as a rule, about 4 cm. in diameter on the average. They are occasionally demonstrated by pyelography. Perirenal air injections can be made but are not without serious hazard. The vast majority of the tumors arise in the adrenal gland and are unilateral. Bilateral tumors are rare. Occasionally the tumors arise from ganglionic tissue in the lumbar region and very rarely in the thorax. So far two cases are on record in whom the tumors were intracranial in position.

It is well to explore the adrenal glands during the performance of a thoracolumbar splanchnicectomy. In this way, tumors will not be overlooked. The thoracolumbar approach with division of the diaphragm is the best exposure for removing a tumor when it is known to be present. When using a technic for splanchnicectomy in patients with essential hypertension which does not permit exploration of the adrenal glands, unusual precautions should be taken to exclude the presence of a pheochromocytoma by appropriate study of the patient.

SUMMARY

The surgical physiology of hypertension is discussed with particular reference to various technics for splanchnicectomy in the treatment of essential and malignant hypertension. Emphasis is placed upon adequate but not too extensive surgery and the careful selection of the procedure best suited to a particular patient.

The physiologic effects of splanchnicectomy upon the cardiovascular system are discussed in detail. The opinion is expressed that the beneficial effect upon the course of hypertensive cardiovascular disease is not due solely to the effect upon basal blood pressure levels but is the result of a combination of effects.

Mortality and survival rates for surgically and nonsurgically treated hypertensive patients are compared. The available evidence strongly

presented. Many variable factors are controlled so that more comparable patients are contained in each group. The mortality and survival rates for each group are given. On the basis of estimated mortality rates from control data in the literature it would appear that surgery has not influenced the course of the disorder in patients falling into Groups 4 and 5.

It does not seem indicated in the treatment of these cases. On the other hand, the prognosis for patients in Groups 1, 2, and 3 appears to be greatly improved. Surgery would seem indicated in patients contained in Groups 2 and 3 and in most of the patients in Group 1. Further control data are desirable, and will be available soon to serve as an additional check upon these conclusions.

The indications for unilateral nephrectomy are mentioned briefly, and the importance of not overlooking the presence of pheochromocytoma in hypertensive patients is stressed

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THE PHYSIOLOGY OF CARDIAC SURGERY

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The physiology of cardiac surgery implies the physiology of all the cardiorespiratory functions. However, it is not proposed to review the basic facts of physiology or anatomy which can be found in standard textbooks, except where these facts apply to the particular problem of cardiac surgery under consideration.

The term "cardiac surgery" also requires definition. Although a great deal of experimental cardiac surgery has been done upon animals, operations upon the human heart have been chiefly confined to the surface or to the walls of the heart. The field of intracardiac surgery on human patients is in its infancy. The physiological principles applying particularly to the following fields of cardiac surgery will be considered: (1) wounds of the heart, (2) operations upon the pericardium, (3) operations designed to improve the blood supply of the myocardium, and (4) intracardiac operations, including those currently performed as well as those projected for the future.

Operations upon the great vessels in the immediate vicinity of the heart will not be discussed, even though some of them have been designed to afford relief from congenital or pathologic abnormalities of the heart itself. Thus, vascular anastomoses between systemic arteries and the pulmonary artery^{6, 16} to increase the amount of blood flowing through the lungs will not be described here. These operations are designed to relieve the symptoms arising from a congenital abnormality of the heart, known as tetralogy of Fallot, but do not correct the malformation of the heart itself. Similarly, the ligation of a persistent patent ductus arteriosus will not be considered; nor will the operation of Sweet²⁰ which consists of anastomosing the azygos vein to a branch of the inferior pulmonary vein in patients with mitral stenosis. All these surgical procedures are related to cardiac surgery but constitute an indirect approach to the problem and therefore will not be considered here.

Any surgeon operating upon the heart should be well acquainted with the fundamental work in cardiorespiratory physiology. There are three or four special considerations in this field which merit particular consideration. The first of these concerns anesthesia.

ANESTHESIA

The history of anesthesia for intrathoracic operations constitutes a brilliant chapter in the adaptation of physiological knowledge to clinical

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problems This history will not be reviewed here. It suffices to say that intratracheal anesthesia should be used in all operations upon the heart.

The Use of the Intratracheal Tube.—The technic of inserting a tube into the trachea under either local or general anesthesia is a relatively simple procedure which can be performed by all medical anesthetists, and which all surgeons interested in thoracic surgery should be able to carry out. With such a tube in the trachea, all types of intrapleural operations in a free pleural space can be performed without danger to the patient from collapse of the lung on the side being operated upon. It is true that a pleural cavity can be opened without such a safeguard and expansion of the lung on the operated side can be maintained by positive gas pressure in a tightly fitting face mask. Such a procedure, however, is only mentioned to be condemned. Laryngeal spasm, edema of the glottis, or the accumulation of tracheobronchial secretions may obstruct the airway with fatal consequences. In addition, the positive pressure of the gas mixture in the tightly fitting face mask, if continued long

eliminates the hazards mentioned above of intrapleural operations performed with only a tightly fitting face mask. The tube insures a free airway at all times which cannot be obstructed by approximation of the vocal cords. Secretions can be readily aspirated from the tracheobronchial tree by a catheter inserted into the trachea through the tube.

Intention of the rubber balloon seals the tube against the trachea, thus preventing the escape of air between the tube and the trachea (Fig. 605). This creates an airtight system between the lung and the anesthetic machine permitting inflation and deflation of the lung at will, and ob-

tube is not
of the heart
free pleural

cavity. Exposure of the heart through a median sternotomy or by resection of costal cartilages and interchondral structures over the precordium on the left side will frequently permit exposure of the heart without opening the pleura. The possibility of accidentally tearing the pleura always exists, however, and because of this, and of the other advantages mentioned above, it is always advisable to employ an intratracheal tube when operating upon the heart.

Choice of Anesthetic Agent.—Any one of a number of anesthetic agents may be chosen for cardiac surgery. The authors have a personal preference for ethyl ether anesthesia. Ether permits the employment of practically 100 per cent oxygen in the gas mixture in the anesthetic machine and the lungs. The only diluents of this oxygen mixture are the small amount of ether vapor and the carbon dioxide exhaled by the

period required to perform even the longest intrathoracic operation is not harmful to the patient. Most other gaseous anesthetic agents must be present in a very appreciable concentration in the gas mixture to exert their anesthetic effect. As the concentration of the anesthetic gas increases, the concentration of oxygen decreases.

It is true that with modern anesthesia, concentrations of oxygen as low as 21 per cent, i.e. that existing in room air, are often sufficient to insure adequate saturation of the arterial blood with oxygen during the course of intrapleural operations. However, a high concentration of oxygen in the gas mixture administered to the patient constitutes a

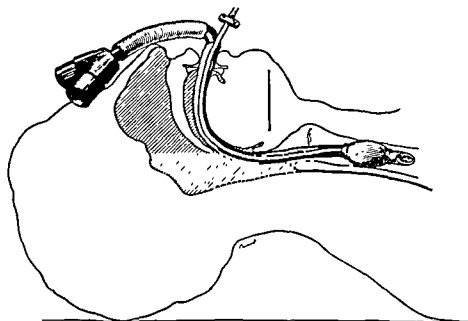


Fig. 605 —Intratracheal tube with inflatable balloon shown in position in the trachea. (Reproduced from *Endotracheal or Intratracheal Anesthesia* by John S Lundy. *S. Clin. North America*, Vol. 25.)

valuable additional safeguard against hypoxemia. Such additional safeguard is of special value in intrapleural operations upon patients with impaired pulmonary function. It is just as important to retain this safeguard in operations on patients with impaired cardiac function. To the authors' mind, there is no valid reason for discarding it.

The argument is occasionally advanced that the use of anesthetic agents such as nitrous oxide or cyclopropane permit a more rapid recovery to a state of full consciousness after the anesthetic is discontinued. It is our experience and that of many others that the skillful use of ethyl ether and oxygen permits a similar rapid return to full consciousness at the conclusion of the operation. Rapid recovery from an anesthetic agent is important for many reasons. The early return of the cough reflex is especially important, since it enables the patient to get rid of any bronchial secretions which may be present.

Mention should be made of the use of cyclopropane in cardiac operations. Disorders of the cardiac rhythm are apt to occur with this anesthetic agent, especially when it is used in elderly patients. It seems advisable, therefore, not to use cyclopropane in operations upon the heart.

Avoidance of Accumulation of Carbon Dioxide in the Body.—Finally, mention should be made of the importance of avoiding accumulation of carbon dioxide in the body during the course of prolonged intrapleural operations. When such an accumulation of carbon dioxide occurs, the tension of carbon dioxide in the arterial blood rises and the pH falls. Beecher² has recently reported the detection of severe acidosis in the course of prolonged intrathoracic operations, the pH falling in some instances as low as 7.00. Such severe acidosis is obviously deleterious, particularly so in cardiac surgery because of its effect upon the muscle fibers of the heart and the conduction of cardiac impulses through the

be prolonged, and systole shortened. If severe enough, acidosis will produce cardiac arrest in diastole. Acidosis also reduces the conductivity of the bundle of His. When severe enough, complete heart block may result. It is particularly important, therefore, in cardiac surgery to avoid the acidosis which may occur in prolonged intrathoracic operations. The acidosis is due to an uncompensated carbon dioxide excess in the blood. It results from failure to remove all the carbon dioxide from the closed gas circuit between the patient's lungs and the anesthetic machine.

Carbon dioxide accumulates in the tissues and the blood as a result of normal metabolism. With a respiratory quotient (the ratio between the carbon dioxide produced by the body to the oxygen consumed) of 0.82, it is obvious that almost as much carbon dioxide must leave the blood in the lungs as oxygen is taken in. For an individual in the basal state, the carbon dioxide which has to be absorbed per minute in the anesthetic gas circuit will amount to between 200 and 250 cc. per minute. If this amount of carbon dioxide is not absorbed, it will accumulate in the gas mixture, the concentration of carbon dioxide in the alveolar air will rise, the tension in the arterial blood will increase and eventually a severe grade of acidosis will develop.

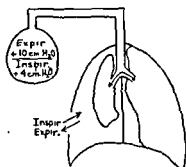
It is the function of the soda lime in the closed gas circuit to absorb carbon dioxide. Provided the soda lime is of good quality, present in adequate amount, and changed whenever it becomes hot from prolonged use, carbon dioxide should be adequately eliminated from the gas mixture. This presupposes, however, an adequate and continuous mixing of the gas in the lungs with that in the anesthetic machine. Obviously, if there is not a continuous movement of gas between the lungs and the anesthesia apparatus, carbon dioxide will fail to reach the soda lime

obtain good
anesthetic

machine constitutes the commonest cause of acidosis in intrathoracic operations.

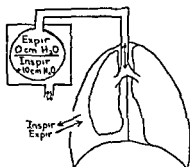
Recent unpublished work in our laboratory and clinic has shown that such acidosis may be avoided by maintaining a good tidal exchange through intermittent compression of the rubber respiratory bladder in the

Constant Flow Positive Pressure



Active Movement
of chest wall & diaphragm

Mechanically Controlled Respiration



No Movement
or slight passive movement
of chest wall & diaphragm

Fig. 606—Sketches illustrating the advantages of intermittent compression of the rubber bag in the anesthetic circuit (right) over dependence upon the patient's respiratory movements for producing an exchange between the rubber bag and the anesthetic circuit and the patient's lung (left). (Reproduced from the Mutter Lecture entitled "Cancer of the Lung" by John H. Gibbon, Jr., M.D., Trans. & Studies of the College of Physicians in Philadelphia. In Press.)

anesthetic circuit. This may, of course, be done manually by the anesthetist, but we believe it can be accomplished more effectively and surely by mechanical means. When the pleural cavity is widely opened, the ordinary muscular movements of respiration are not effective in obtaining an adequate movement of gas in and out of the lungs. When the diaphragm descends and the ribs swing upward and outward, the size of the thoracic cage is increased. When the chest is intact, this results

in the passage of air through the open glottis into the lungs. When one pleural cavity is widely opened, these conditions do not occur. When the

in through the operative wound, rather than entering the lung through the trachea and bronchus. Also, unless it is rigidly fixed, the mediastinum will swing to the opposite side with an inspiratory movement. The additional space in the opposite hemithorax made available by the inspiratory movement will be occupied by the mediastinal structures rather than by an increase of air within the lung on that side. Provided a high concentration of oxygen is maintained within the closed system between the lungs and the anesthetic circuit, severe degrees of unsaturation of the arterial blood with oxygen will not occur despite the inadequate exchange of gas between the lungs and the machine. Carbon dioxide, however, will accumulate in the alveolar air. It is essential, therefore, to supplement this inadequate exchange of gas, which occurs from the ineffectiveness of the respiratory movements under these conditions, by intermittent compression of the rubber bladder in the anesthetic circuit. In the past nine months, we have employed intermittent mechanical compression of the respiratory bladder using either the Mautz¹¹ or the Crafoord⁷ apparatus, in more than 140 intrathoracic operations. We have been able by this means to avoid acidosis in prolonged intrathoracic operations (Fig. 606).

THE AVOIDANCE AND CORRECTION OF DISORDERS OF CARDIAC RHYTHM

The observance of the physiological principles outlined above with

itself, certain additional precautions must be observed to avoid disturbances of cardiac rhythm. Whether the surgeon be suturing an incised or penetrating wound of the heart, or removing thickened and calcified pericardium, or attempting to increase the blood supply to the myocardium by some means, or whether he is actually entering one of the cardiac chambers to remove foreign bodies or cut stenotic valves, he must, if possible, avoid producing disorders of the cardiac rhythm by his manipulations.

The surface of the heart itself is irritable, and irregular contractions may be produced by mechanical stimulation. The least harmful of these, perhaps, is the production of *extrasystoles*, which tend to disappear when the mechanical stimulation ceases. Rough handling of the organ should, of course, be avoided. Gentle traction transmitted through a suture placed in the apex or upon the auricular appendage is surprisingly well tolerated. Slight displacements of the heart by gentle pressure,

yielding a little with each heartbeat, can usually be carried out without ill effect. Bathing the surface of the heart with 1 per cent procaine solution will tend to reduce the irritability of its surface and enable the manipulations mentioned above to be carried out with less likelihood of producing disturbances in rhythm. Similarly, the intravenous injection of 0.1 per cent procaine solution given slowly will also tend to reduce the irritability of the heart during manipulation, as well as help to initiate the return of normal rhythm after irregularities have appeared.

The most serious disturbance of cardiac rhythm is *ventricular fibrillation*, which will rapidly result in death unless promptly corrected. Beck² has demonstrated that passing an electric current through the heart by means of two, broad, well-padded electrodes directly applied to opposite sides of the heart will frequently result in the re-establishment of normal rhythm. The electrical shocks administered in this fashion may have to be repeated several times, with intervals of rest between the shocks, before normal rhythm is established. This is probably the most effective method of re-establishing regular rhythm in the presence of ventricular fibrillation when operating upon the heart. It is advisable, therefore, to have such an apparatus available and ready for instant use when performing major operations upon the heart, especially when the myocardium is diseased or the coronary blood supply is inadequate.

Intermittent compression of the ventricles of the heart by manual means is a most effective method for maintaining some degree of circulation and for restoring the normal rhythm in cases of cardiac arrest or ventricular fibrillation. It is commonly referred to as *massaging the heart*. The term is obviously inaccurate. The procedure should consist of intermittent compression of the ventricles at a rate somewhat slower than the normal beat, allowing adequate time for diastolic filling between successive compressions. The procedure should be employed immediately in all instances of cardiac failure from whatever cause during operation upon the heart. It is particularly important that it be carried out from the moment ventricular fibrillation begins until the electrodes are in position to shock the heart into normal rhythm. By this means, some degree of circulation will be maintained until the normal cardiac output is restored with a return to normal rhythm.

In addition to disturbances of rhythm which may occur during manipulation of the heart, it is important to avoid any procedure which will interfere with the organ's normal function of the forward propulsion of blood. For example, in wounds on the posterior surface of the left ventricle, it is frequently necessary to dislocate the heart from its normal position in order to obtain adequate exposure for suturing the wound. Whether this is accomplished by traction upon a suture in the apex of the heart or by manually dislocating the heart upward, care must be taken not to hold the heart in this position any longer than necessary. The degree of dislocation should also be as little as possible in order to accomplish the required purpose. Marked displacement of the apex of

the heart upward and out of the chest is very poorly tolerated. Cardiac filling and output are reduced and disorders of rhythm are likely to occur.

The auricular appendages can be handled, traumatized, incised and even excised¹⁰ with great impunity. Harken⁹ and Bailey¹ have recently used an incision in the auricular appendage in order to divide a stenosed mitral valve on human patients. Madden¹⁰ has actually advocated and practiced excision of the left auricular appendage to prevent arterial emboli from mural thrombi in patients with mitral valvular disease. Experimentally, it has been shown that other portions of the heart can be successfully excised. Gordon Murray¹¹ has recently reported the successful excision of infarcted areas of the ventricles in animals. Whether this procedure will every find clinical application in coronary artery occlusion in human patients has not been determined.

It should be borne in mind when handling episodes of cardiac failure during operations upon the heart that epinephrine has the effect of increasing coronary blood flow, its action upon the coronary vessels being similar to that produced by stimulation of sympathetic nerves. This is, of course, an exactly opposite effect to that produced in blood vessels supplying the skin, which are constricted by epinephrine and sympathetic nerve stimulation. This drug, therefore, may be of some use in critical emergencies occurring with cardiac failure during operations upon the heart.

INTRA-ARTERIAL TRANSFUSION

Having discussed the physiological principles involved in the surgical approach to the heart and the reactions which may occur during the course of manipulations of the organ itself, it is appropriate to consider methods of combating the critical situation which arises because of a

wounds of the heart the hemorrhage has already occurred, and is often continuing, when the heart is operated upon. In opening a thin-walled, dilated left auricle for the purpose of introducing an instrument to divide

level. A rapid hemorrhage requires an equally rapid replacement. The larger the hemorrhage, the shorter is the time that the patient can survive the blood loss

Recently, Robertson and co-workers,¹⁷ and Porter and his associates¹⁸ have demonstrated that where the blood volume is seriously depleted an intra-arterial transfusion administered with great speed is far more effective in restoring the circulation to normal than an equal volume of blood, or even at the same rate gained by injecting blood

rapidly into an artery is quite obvious. By this means, the blood pressure is rapidly restored to normal. This immediately restores the coronary blood flow to normal, since the coronary blood flow is dependent upon the aortic blood pressure. Thus, the vicious cycle of depleted blood volume, lowered aortic blood pressure, decreased coronary blood flow and hypoxia of the myocardium is at once reversed. On the other hand, when large amounts of blood are transfused rapidly into a vein of a patient with a severely depleted blood volume and lowered blood pressure, a sudden burden is placed upon the right heart and then upon the

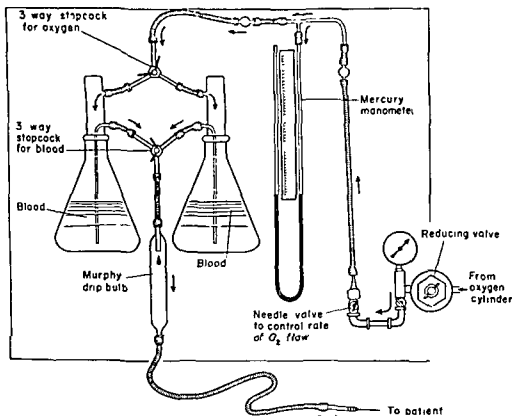


Fig 607.—Diagram of apparatus for intra-arterial transfusion (Porter, M. R., Sanders, E. K. and Lockwood, J. S. in *Annals of Surgery*, Vol. 128.)

left heart before any improvement occurs in the coronary blood flow. Under these circumstances, it is not surprising that patients in profound shock fail to rally with large intravenous blood transfusions.

It would be a mistake to assume in this discussion, of course, that the slow intravenous administration of blood, during the course of a prolonged operation with a steady, slow, continual loss of blood, is not still the safest, best, simplest, and most appropriate method to use to maintain a normal circulating blood volume. In any type of cardiac surgery, however, where the danger exists of sudden profuse hemorrhage from a cardiac chamber, it is advisable to have at hand and immediately available, an apparatus for the rapid intra-arterial transfusion of oxygenated blood (Fig. 607).

BLOOD VOLUME

In all major operations an appreciable blood loss occurs. It is now common surgical practice to replace this blood loss as it occurs during the course of the operation. Thus the patient's cardiovascular system is never handicapped by even a temporary depletion of the circulating blood volume. In operations upon the lungs, Miller and his co-workers¹² have recently shown that the blood loss in an exploratory thoracotomy is in the neighborhood of 1000 cc.; in a lobectomy approximately 1500 cc.; and in a pneumonectomy, roughly 2000 cc. In elective operations upon the heart the loss of blood, which occurs in the absence of unexpected hemorrhage, is probably considerably below these figures. Nevertheless, it is advisable to replace by transfusion whatever blood is lost.

The amount of blood to be transfused can only be determined with accuracy during an operation by the method suggested by Wangensteen¹³ of weighing gauze sponges before and after their use. The increased weight of the sponges saturated with blood affords a good clinical index of the blood loss. Miller and his associates¹² have recently stressed the difficulty of estimating the blood loss by changes in blood pressure and have pointed out that the blood pressure may be maintained by the dye method. . . . of the blood loss . . . of the operation . . . tions it . . . operation had been inadequate; . . . as determined by the dye method. In these . . . patients the sponges used in the operation were not weighed. In twenty-seven similar operations, the sponges used were weighed and in only three of these patients was the blood loss inadequately replaced, and then only by small amounts. Thus in elective major operations upon the heart it is advisable to weigh the gauze sponges before and after use. This will give a continuous record of the blood loss and permit simultaneous accurate replacement by blood transfusion.

CARDIAC TAMPONADE

Cardiac tamponade occurs when there is an accumulation of fluid or air in the intact pericardial sac. It results in an elevation of venous pressure, a decrease in the pulse pressure and a decrease in cardiac output. The condition is adequately described in standard textbooks, and does not require elaboration here. It is merely mentioned here to caution the operating surgeon not to attempt to suture the pericardial sac after an operative procedure upon the heart. If the pericardium is tightly sutured, serosanguineous fluid may accumulate within the pericardium producing cardiac tamponade. It is advisable, therefore, not to close an incised wound in the pericardium. It is even desirable, under certain circumstances, to have the opening in the pericardium communicate freely with one of the pleural cavities. If this is done the fluid can pass

freely into the pleural space where it can be readily aspirated. Cardiac tamponade cannot occur under these circumstances.

An opening in the pericardium, just large enough to permit herniation of the heart through it, may be dangerous. Bettman⁴ has reported a case in which such an opening was left following the removal of a portion of the pericardium during the course of a pneumonectomy for carcinoma of the lung. After the operation the patient went into profound shock. He was reoperated upon, and the heart was found to have herniated through the opening in the pericardium resulting in marked dislocation from its normal position. The defect was enlarged, allowing the heart to return to its normal position, and the patient recovered. Small and very large defects are without danger, but defects of a size through which the heart may herniate (in Bettman's case $2\frac{1}{2}$ inches in diameter) should be avoided.

THE FUTURE DEVELOPMENT OF INTRACARDIAC SURGERY

Operations within the human heart at present must be performed without direct vision of the structure being operated upon. There has recently been a revival of interest in operations designed to relieve the stenosis of diseased cardiac valves.^{18, 9, 1} The operations are performed by thrusting a knife or some other cutting instrument into one of the chambers of the heart and dividing the stenosed valve. Murray¹⁴ has attempted to reduce the size of cardiac septal defects in children by passing heavy suture material blindly across the defects. When the sutures are drawn tight, the size of the defect in the septum is diminished.

There are obvious disadvantages and dangers to such blind procedures. It is hard to picture a promising future for cardiac surgery unless the flow of blood through the heart can be temporarily diverted. If this could be safely done, an incision could be made through the wall of the heart and a valve or septum operated upon under direct vision. Grafting of tissue may be necessary to repair defects in the septae between the ventricles and the auricles. It is conceivable that diseased and calcified cardiac valves could be replaced with grafts of suitable tissue which would function satisfactorily provided that time were available and adequate exposure of the part to be operated upon could be obtained. Experimentally it has been shown by Templeton and Gibbon²¹ that a graft of pericardium may be successfully employed to replace an excised leaflet of the tricuspid valve in dogs. These operations were performed rapidly under direct vision through an incision in the right auricle, after clamping both venae cavae. The venae cavae can be safely clamped for only a few minutes in a dog without producing death from ventricular fibrillation or cerebral damage.

Experimentally it has been shown that life can be temporarily maintained in animals without any blood flowing through the heart and lungs, by means of a perfusion apparatus, followed by prolonged survival. In 1939 Gibbon⁸ reported the successful artificial maintenance of life

by such an apparatus in cats for as long as twenty minutes, followed by survival. In 1948 Bjork⁶ reported the prolonged survival of a dog following occlusion of both venae cavae for thirty minutes. During occlusion of the cavae, the dog's brain was perfused with oxygenated blood. In 1949 Stokes and Gibbon¹⁹ reported the survival of eight dogs following occlusion of both venae cavae for from thirty to forty-six minutes. During occlusion of the cavae the entire body of the animal was perfused with oxygenated blood.

The apparatus required to achieve these results is relatively simple. It consists of three chief elements. The first is a pump to withdraw blood continuously from the superior and inferior venae cavae. The second is an apparatus to provide for the elimination of carbon dioxide and the uptake of oxygen by the blood. The third element is another pump to return continuously the oxygenated blood, from which the carbon dioxide has been removed, to the systemic arterial circulation of the animal. This extracorporeal circulation of blood provides an artificial substitute for the essential functions of the right heart, the lungs and the left heart. This simplified description omits the large number of technical difficulties which remain to be overcome before such an apparatus can be safely used to take over temporarily the functions of the heart of human patients. None of these technical difficulties are insurmountable. If it is ever possible to perform cardiac surgery in human patients it is obvious that great progress will have to be made in the use of such an apparatus. It will have a place in intracardiac surgery.

SUMMARY

1. The heart may only be safely approached when suitable anesthetic methods are available. The most important of these is the maintenance of an adequate airway. Adequate oxygenation of the arterial blood is essential but not difficult to achieve. Of equal importance is the elimination of carbon dioxide and the avoidance of acidosis. This can only be accomplished through adequate ventilation of the lungs.

2. The likelihood of disturbances of cardiac rhythm can be diminished by care in the manipulation of the heart and the employment of certain drugs.

3. An adequate blood volume should be maintained at all times. Intra-arterial transfusions are of great value in restoring a normal circulation following hemorrhage.

4. Cardiac tamponade should be avoided.

5. Intracardiac surgery will be greatly advanced by the development of a mechanical method of temporarily taking over the functions of the heart and lungs.

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CARDIAC RESUSCITATION

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A sufficient number of patients have been returned to normal health following cardiac resuscitation to make it evident that effort expended in that direction is worthwhile. It is equally evident to those interested in this field that if the occasional patient whose heart is in asystole is to be resuscitated, the operating team involved must act quickly, according to a preconceived plan. It is unlikely that any patient will be saved by a surgeon who has not previously thought out his plan of attack.

When a patient develops sudden cardiac arrest, the greatest problem is that of speed in making the diagnosis and instituting treatment. The brain must not be deprived of oxygenated blood for more than three to four minutes. Therefore, within this short period of time, the surgeon must produce an adequate blood flow by cardiac massage and the anesthetist must insure oxygenation of the blood by adequate ventilation of the lungs.

Since cardiac arrest is an emergency in which one cannot wait for consultation it would seem to be worthwhile for every surgeon and anesthetist to understand the various aspects of this problem so that a life may be saved if the opportunity should present itself.

ETIOLOGY

The cause of cardiac asystole has a great deal to do with the prognosis. Thus when one is thinking of cardiac resuscitation, death from the usual medical causes is not included. Success can seldom be expected unless the emergency arises in the operating room. Even then success is unlikely when dealing with a patient with severe myocardial injury.

A favorable situation for cardiac resuscitation is that of a patient with a normal heart who has received an overdose of an anesthetic. Here the problem is simply that of producing artificial circulation and respiration until enough of the anesthetic agent is removed, or destroyed, to allow the heart to start beating again. This includes not only patients under general anesthesia but also patients who are sensitive to or perhaps have received an intravenous injection of a local anesthetic.

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When cardiac arrest or ventricular fibrillation is incident to anoxia, the brain may well have been damaged considerably before cardiac action ceased. The period of arrested circulation which can be tolerated is decreased accordingly (Case IV).

It is sometimes difficult to account for sudden cardiac arrest when the heart has no demonstrable lesion and anoxia or an overdose of an anesthetic does not appear to be a contributory factor. It has been thought that reflex phenomena (vago-vagal reflexes) are responsible. In such a situation the heart will usually start beating again rather easily, and if the time interval is not over three minutes the prognosis is good (Case I).

DIAGNOSIS

Delay in diagnosis is the chief cause of failure in cardiac resuscitation. The anesthetist must maintain constant observation of the patient if he is to notice asystole the moment it occurs. Having noticed the absence of a pulse or blood pressure the question always arises as to whether the heart is beating so feebly as to be undetectable. In such instances a fatal delay is caused. The anesthetist must be sure before proceeding with the proper treatment.

If the surgeon happens to be operating in the vicinity of the heart or a large artery he may immediately confirm the diagnosis by putting his hand directly on the heart or large artery. If the surgeon is operating in the abdomen his first reaction should be to feel the heart through the diaphragm.

Auscultation of the chest is not apt to be helpful when the pulse and blood pressure are not obtainable. If the heart is beating so feebly as not to give a pulse or sustain the blood pressure it is unlikely that it can be heard with a stethoscope. Time spent by the surgeon looking for a stethoscope if one is not immediately available is time ill spent.

It has been reported that one may diagnose cardiac arrest immediately with an ophthalmoscope.¹ It is said that the retinal arteries will not be visible and the column of blood will be broken up into short segments in the veins. We are convinced, on the basis of personal experience, that this method is of no practical value, and doubt that it is reliable even in the hands of an experienced ophthalmologist.

It has been suggested that the absence of capillary refill indicates cardiac arrest. We can say that the presence of cardiac refill does not necessarily indicate cardiac activity for we have observed it as long as half an hour after the heart had been seen to be still.

Even if one happens to have an electrocardiograph attached to the patient at the time of cardiac arrest it may not be helpful, for Negovski² has observed that the heart can produce an electrocardiogram, though an abnormal one, for some time after it has stopped beating.

It becomes obvious from the above that the only reliable method of determining whether the patient is in cardiac asystole is to see or feel

the heart or a large artery. We are convinced therefore that the surgeon should take the point of view that opening the thorax to feel the heart is a diagnostic procedure. We believe that when the patient's pulse and blood pressure suddenly cannot be obtained, the chest should be opened immediately without losing valuable time attempting unreliable diagnostic procedures.

Once the decision has been made to open the chest the surgeon should be prepared to do it with the greatest dispatch. Every surgeon therefore should give some thought as to the quickest and easiest method, should the occasion arise. The surgeon needs only a pair of gloves and a scalpel. Given these he should have his hand on the heart in ten to fifteen seconds. Skin antiseptics and sterile drapes are refinements which can be added when available but their absence should not cost the patient his life.

The incision should be made in the left fourth interspace from about the edge of the sternum to the posterior axillary line. Since there is no bleeding the incision can be carried quickly through the chest wall and pleura. The surgeon can then readily put one hand between the fourth and fifth ribs to feel the heart. The diagnosis will be immediately apparent. If arrested the heart will be still and if in ventricular fibrillation it will feel like a "bag of worms."

TREATMENT

In the presence of cardiac asystole the problem is one of producing adequate blood flow by cardiac massage and adequate oxygenation of the blood by artificial ventilation of the lungs.

Respiration.—Adequate respiration can be maintained with an anesthesia machine, by manual compression of the breathing bag. A tight-fitting face mask is satisfactory. It is not wise to take time to insert an endotracheal tube until the patient is again well oxygenated. One hundred per cent oxygen should be used.

If the emergency should arise out of the operating room, the bag and mask technic, or the Kreiselman bellows resuscitator can be used. Until they are available the patient's lungs should be ventilated by the mouth to mouth technique.

Circulation.—As soon as the surgeon puts his hand on the heart and finds it is not beating he should start compressing it rhythmically. If a rib spreader is not immediately available he should divide the fourth and fifth cartilages with a knife or scissors in his left hand as he compresses the heart with his right hand in order to give better exposure and prevent the ribs from pressing against his hands. Even after this the rib spreader is of great help. Following cardiac massage a few open vessels will begin to bleed and must be caught as soon as hemostats are available.

There are a number of factors which greatly influence the effectiveness of the blood flow produced by cardiac massage.

1. *Rate of Cardiac Massage.*—A review of the literature reveals a dif-

ference of opinion as to the rate at which the heart should be compressed. Most writers recommend twenty to forty times a minute, in order to allow the ventricles to fill adequately, while a few have suggested a normal rate.

Because of this difference of opinion we recently studied the problem in dogs. The results are reported elsewhere.³ Using the bubble meter of Dumke and Schmidt⁴ in the thoracic aorta, it was found that a greater blood flow was produced when the heart was compressed at a rapid rate. Rates of 30, 60 and 120 per minute were compared. In all instances the blood flow increased as the rate of compression was increased regardless of whether the heart felt full or empty.

As the result of these experiments we became convinced that in clinical use one should compress the heart as rapidly as possible, up to 120 times per minute. The fatigue of the operator makes a rate of 120 times per minute impossible for more than a few minutes whereas he can continue for a long time at sixty to eighty times per minute. If there are two or more operators who can take turns, a faster rate may be constantly maintained.

2 *Technic of Cardiac Massage.*—In the laboratory it was found that some practice was required to produce an effective blood flow by cardiac massage. The dog's heart can be compressed most effectively by placing the thumb in front and the fingers behind, or the thumb and index finger in front and the other three fingers behind the heart. It was found that the blood flow produced by compressing the heart against the anterior chest wall was only about one-half as great as by the above method. Only one-fifth as much blood flow could be produced by compressing the heart through the diaphragm with one hand in the abdomen.

The amount of blood flow produced by artificial respiration alone was too small to be measurable by this technic. Any hope that artificial respiration is an effective method of producing blood flow should be abandoned.

A small human heart may be compressed with one hand, as in the dog. The usual adult heart can be more effectively compressed, with less effort, by placing one hand in front and one behind the heart.

3. *Blood Volume.*—It was found in the laboratory that the filling of the heart is very important in producing an effective blood flow even though it was not profitable to wait for it to fill between cardiac compressions. The cardiac output varied directly with the rate. Nevertheless the cardiac output could be greatly increased by rapid transfusion of blood, plasma or plasma substitutes. When intravenous fluids were given rapidly the heart could be felt to fill more completely and the cardiac output was found to be increased greatly even though the compression rate remained the same.

When the heart is compressed the heart will resume

brain since it is most severely affected by anoxia, whereas in normal adults the descending thoracic aorta can be clamped for 30 minutes with no ill effects. We were able to show that the carotid blood flow was greatly increased by occluding the aorta.

Drugs.—We have felt that no drugs are helpful in getting the heart to start beating again. Once the heart has started epinephrine may be useful in increasing the tone of the cardiac muscle and the effectiveness of its contraction. We have seldom used it. It does increase the probability of ventricular fibrillation.

Procaine may be useful to decrease the likelihood of the development of ventricular fibrillation, and in restoring normal rhythm in the event of ventricular fibrillation. We use it routinely.

Ventricular Fibrillation.—If, when the thorax is opened, the heart is found in ventricular fibrillation, or if it should develop during the cardiac massage, the problem takes on another aspect.

The usual causes of ventricular fibrillation are anoxia, mechanical trauma, electric shock, and drugs which increase the irritability of the heart. Clinically, anoxia results commonly from coronary occlusion, or respiratory obstruction during anesthesia. The heart may be stimulated by manipulation during many intrathoracic operations but ventricular fibrillation has occurred most commonly during operations upon the heart and pericardium. Local and intravenous procaine have been shown both experimentally and clinically to protect the heart against irregularities resulting from mechanical stimulation.⁵

In rare instances ventricular fibrillation has reverted to normal rhythm spontaneously. In some the use of drugs may cause reversion, as happened recently in one of our patients (Case IV). Nearly always, however, countershock therapy, developed by Wiggers⁶ and by Beck and Mautz⁷ must be employed. This method of treatment is based on the observation that passage of a strong current through the heart will cause a simultaneous contraction of all the incoordinated, fibrillating fibers, and relaxation follows. The heart is then in standstill. In animals, the spontaneous heartbeat resumes after a short period of cardiac massage. In the patients' hearts defibrillated by us, the spontaneous heartbeat has begun after a short interval of standstill.

Before defibrillation is attempted, anoxia must be overcome by cardiac massage and artificial ventilation of the lungs with 100 per cent oxygen. Three cubic centimeters of 2 per cent procaine are injected into the right ventricle and an equal amount into the pericardial cavity unless procaine has previously been given intravenously. The electrodes are then placed on each side of the ventricles and an alternating current (60 cycles) of 1 to 1.5 amperes is passed through the heart for less than a second. Repetition of the shock may be necessary. The strength of the current is of importance, for it has been shown that, in animals, 0.4 amperes for 5 seconds will cause fibrillation, whereas 0.8 amperes or more will stop it. A current of 0.8 amperes will not cause fibrillation and 0.45 amperes will not stop it.⁸

hours after operation her blood pressure began to fall, she lapsed into coma, and her heart stopped beating within an hour.

At autopsy this patient was found to have extensive myocardial fibrosis. Had it not been for preexisting myocardial disease she might possibly have recovered. There probably would have been permanent cerebral changes of at least moderate degree. The period of cardiac arrest was probably between four and five minutes.

CASE VI E D, a woman aged 29, had returned to her room following a total hysterectomy four hours previously. She had not recovered sufficiently from anesthesia to recognize her husband but was tossing about the bed and, because of this, was given $\frac{1}{4}$ grain of dihydral. A short time later, after being out of the room, her husband returned and found her blue and gasping for breath. A few minutes later artificial ventilation with a Kreiselman bellows was started and from ten to fifteen minutes later a surgeon was called. Since her color had improved with artificial ventilation of the lungs, an attempt at resuscitation was made. The left chest was opened through the fourth interspace and the fourth and fifth costal cartilages were divided. The heart was still. After cardiac massage for one and one-half to two minutes ventricular fibrillation was noted. While waiting for the defibrillator, procaine 100 mg. was given intravenously and normal spontaneous rhythm resumed, with contractions becoming increasingly strong. After operation spontaneous respirations did not resume and reflexes could never be obtained. The patient died thirty hours later in a respirator.

It seems likely that the death of this patient was due to respiratory obstruction and the cardiac arrest to anoxia.

Comment.—These case reports illustrate many of the points discussed above. The only patients who recovered fully were those in whom cardiac arrest occurred on the operating table or in the anesthetizing room. Prompt diagnosis and treatment averted injury to the anoxia-sensitive brain cells. In all of these patients the heart responded quickly to manual stimulation and resumed its normal rhythm.

Case V is of unusual interest because an attempt at cardiac resuscitation in a patient who apparently died spontaneously has not been previously recorded, to our knowledge. The occurrence of ventricular fibrillation in Cases V and VI, which followed standstill and cardiac massage, was probably largely due to increased irritability of the cardiac muscle resulting from anoxia. It is probably because of the close interrelationship of anoxia and ventricular fibrillation that defibrillation in humans has been discouragingly unsuccessful. As far as we know, Beck¹⁰ has had the only fully successful case of defibrillation.

SUMMARY

1. The methods and techniques which had proved successful in resuscitating patients with cardiac arrest and ventricular fibrillation have been discussed.

2. Success in cardiac resuscitation depends upon the restoration of the flow of oxygenated blood to the brain within three to four minutes. All other considerations are of secondary importance.

3. Since the time limit of three to four minutes cannot be exceeded when this emergency arises, all surgeons and anesthetists should become familiar with the technic of cardiac resuscitation.

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CARDIAC PROBLEMS IN THE SURGICAL PATIENT

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THE PREOPERATIVE EVALUATION OF THE CARDIAC PATIENT AS A SURGICAL RISK

The problem of evaluating the cardiac risk of operating on a patient with proved or suspected heart disease sometimes *seems* complex and difficult. Sometimes it is perplexing and will demand all your knowledge and wisdom. Yet there are certain relatively simple principles upon which one can depend, and certain common pitfalls which one should keep in mind and avoid.

The Fundamental Principle.—The fundamental principle is quite simple. A surgical operation is somewhat analogous to an athletic contest. Whether or not a patient will go through it safely from the cardiac standpoint depends to a considerable extent on whether or not he gets dyspnea or anginal pain when he exercises; and on how much exercise he can take without producing these symptoms. Consequently, the most important thing to be determined, in order to evaluate the operative risk from the cardiac point of view, is the patient's exercise tolerance.

Determining the Patient's Exercise Tolerance.—Determination of the exercise tolerance does not require the aid of any special instruments. It is *not* determined by studying the response of the patient's blood pressure or pulse to exercise. It is determined primarily by questioning the patient carefully. The following questions will open the interview: "Can you go about your daily tasks, walk as far as you want to, keeping up with people of your own age, and climb two or three flights of stairs?" If the patient is a housewife one can often get a picture of the situation by asking, "Do you do all your housework including your laundry?" (When a woman's exercise tolerance is reduced, the first thing she stops doing is the laundry.) If the true answer to either of these questions is "yes," then the patient is essentially a normal risk for surgery. If the answer is "no," then you should ask, "What stops you from doing these things?" There are two symptoms which stop patients which are important: dyspnea and anginal pain. I wish to discuss these in some detail.

Dyspnea.—If the patient has myocardial insufficiency he will have dyspnea on effort. Yet since we all have dyspnea on effort, this symptom must be evaluated on the basis of the amount of effort necessary to pro-

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† This discussion will deal strictly with the heart; it will not cover the extra-cardiac circulatory problems which are of prime importance from the standpoint of management of blood pressure during anesthesia

duce it, and upon the noncardiac factors which can contribute to it, such as age, weight, anemia, asthma, *psychologic factors and the like*. The point to be determined is—is the patient more short of breath than he ought to be when these factors are taken into consideration? If so, the probability exists that he is *dyspneic because of heart disease*. Some patients are “stopped” by a relatively mild degree of dyspnea, especially if they are nervous about their hearts. Thus, it is helpful to have some conception of what constitutes a real “end point.” When a person is really “stopped” by myocardial insufficiency he is not only dyspneic, but “all in,” “tired all over” and “can’t go any further.” It sometimes clarifies the situation if you ask a patient, “if there were a bear after you, could you climb another flight of stairs?” If he is really “stopped” by myocardial insufficiency he will tell you, “the bear would get me”. If, after questioning the patient carefully, you still don’t feel sure you have a clear picture of his exercise tolerance, take a walk with him along the hospital corridor. If he does well on that test, take him up a flight or two of stairs with you. This will often clarify any doubt which may exist in your mind after talking to him. The points to be noted are his general appearance and the development of manifest distress, rather than the actual rate of pulse or respiration. Sometimes a patient, with edema from a peripheral rather than a cardiac cause, has been thought to have a cardiac contraindication to operation, especially if he also has a murmur or an elevation of blood pressure. If the patient can walk with you as described above, the chances are small that his edema is due to cardiac failure.

Anginal Pain.—If the patient has coronary insufficiency he will have pain or “distress” on effort. Many errors are made in recognizing and evaluating this symptom, because the patient is not questioned carefully enough, or the examiner does not know what angina feels like. Consequently, although there is some risk of being too elementary, these questions and their answers will be outlined.

The first question is “*exactly where is your pain or distress?*” Angina of effort is, with few exceptions, under the sternum; or in the midline just above or below the sternum, or located in a bilaterally symmetrical distribution to either side of it. A midline discomfort in the chest on effort is angina till proved otherwise; a unilateral discomfort, at the cardiac apex, or in the left upper chest is not angina until proved otherwise.

The second question is “*what does it feel like?*” A patient with typical angina, who has not as yet developed a glib answer as a result of much practice, will respond to this question with a puzzled pause, because the sensation is difficult to describe. Then he will often answer, “well it isn’t exactly a pain, it is a tight feeling,” or a “pressing,” a “burning,” a “dull feeling” or a “choking” sensation, “like gas.” He may say, “it goes up to my throat and chokes me.” A patient who tells you it is a “visc-like pain” has usually learned this description from his doctor,

or from reading medical books. It is not a terminology which patients tend to invent spontaneously. It should be stressed that anginal pain is almost never sharp or lancinating. Patients will often tell you the pain is "sharp" but if you question them carefully you will find that the adjective "sharp" has been used as a synonym for "severe," by a person of limited vocabulary.

The *third question* is, "*What makes the pain come on?*" The answer is "when I walk, especially when I hurry." Exercise is the prime cause. Contributory factors are "after eating," "out doors in the cold," "a wind," "a hill" or "a stair," or emotional disturbance. But exercise is the cause; and the pain comes on *during exercise*.

The *fourth question* is "*How long does it last?*" The answer is, "it stops quite promptly when I stop walking." It doesn't last longer than a few minutes. The patient will slow his pace, stop and look in a store window; he may lean against an upright support, or sit down in a chair if one is available. He will usually not lie down during an attack of angina.

To sum up this elementary thumbnail sketch, a patient who is stopped by angina of effort will describe a dull, tight, constricting, choking or burning sensation in the chest, usually in the midline, coming on during effort, and relieved promptly by rest.

The following type of pain is common; it has often deprived a patient of the opportunity of being subjected to a necessary operation. It will be described in the terms of question and answer:

Q. "Do you have pain in the chest when you work?"

A. "Yes."

Q. "What does it feel like?"

A. "It's a nagging pain, a sort of soreness."

Q. "What makes it come on?"

A. "When I get tired."

Q. "During work?"

A. "No, usually after a hard day's work, after I sit down."

Q. "Where is it?"

A. (Patient indicates the region of the second left interspace.)

Q. "How long does it last?"

A. "Hours, till I get rested."

I do not know the mechanism of production of this pain. It is seen most often in women over 40 years of age. It is not angina of effort, and it does not seem to be of great importance in evaluating a surgical risk from the cardiac point of view.

Other Factors.—If the patient has definite angina of effort, it is important to determine two other facts:

1. Did he have a cardiac infarction in the past, and if so, how long ago? To do this it may be necessary to inquire not only concerning a former "heart attack" but also concerning the diagnoses under which a coronary occlusion so often hides its identity; i.e., indigestion, pneumonia, gall-bladder attacks, pleurisy and so forth, or any fairly severe illness accom-

panied by pain in the epigastrium, chest, neck or arms. If he has had such an attack, you must be sure that healing is complete, before subjecting him to an elective operation.

2 Has the angina of effort stayed about the same in the past six months, with regard to severity, duration, and amount of effort necessary to produce it? Recent change in these characteristics indicates the possibility that changes may be taking place in the coronary circulation, and that a new infarction may be in the offing. Under such circumstances conservatism is in order.

The Decision.—Now, after you have determined the patient's exercise tolerance, and have tried to be sure, in patients with angina of effort, that the process in the coronary arteries is more or less static, and that nothing new is brewing, it is possible to assign the patient with heart disease to one of the four following groups:

1. *Normal exercise tolerance.* He can exercise normally, walk as fast and as far as he wants to, and climb three flights of stairs.

2. *Slightly reduced exercise tolerance.* He can get around, but has to slow down more than the average individual of his age, height and weight, and after two flights of stairs he has to stop.

3. *Markedly reduced exercise tolerance.* He can just about get up one flight of stairs.

4. *No exercise tolerance.* These patients usually have some of the signs of congestive heart failure (cyanosis, increased venous pressure seen in the cervical veins, pulmonary congestion, hepatic engorgement, edema).

If the patient is in Group 1 or 2 and can exercise normally, or with only slight restriction he is, in general, a normal operative risk from the cardiac point of view. As an example, a patient, aged 58 needed a cholecystectomy, but an electrocardiogram taken during the preoperative evaluation showed a right bundle branch block, and I was asked to decide if it was safe to operate. My examination disclosed the fact that she was in the habit of walking four miles a day "for the exercise," and that she had never had coronary or other cardiac symptoms. Of course, she was put through a careful, complete examination, to impress her with the fact that I was not making a snap judgment. However, the crux of the situation was that she could walk four miles. She went through operation without untoward incident.

If a patient is in Class 4, operation is contraindicated, except under unusual conditions.

When a patient is in Class 3 and can just about get up one flight of stairs, the decision is often difficult. It depends, primarily upon weighing carefully the degree of reduction of exercise tolerance against the need for the operation (i.e., the benefit to be derived from it). In such cases you should ask the surgeon, "What are the indications for operation?" "How necessary is an operation for his survival, and future health and happiness?" This aspect, in many instances, is not given enough weight by the medical consultant. It seems to me inexcusable to make an old

gentleman lead a catheter life, unless he wants to do so, if there is a fairly good chance of his surviving a prostatic operation. If he can get up one flight of stairs, and if, after bladder drainage, he has adequate renal function, his chances of surviving operation are remarkably good, if the anesthesia is managed skillfully, and if, after operation, the surgeon will avoid excess intravenous fluid administration.

Most medical consultants seem to me to be too afraid of surgery in patients with heart disease. If the anesthetist is capable, the heart does not have as much strain placed upon it during operation as seems to be generally feared.

Pitfalls to Be Avoided.—There are certain factors which should be kept in mind when making decisions regarding operation which do not fall under any of the categories mentioned above.

The Patient with Acute, Upper Abdominal, Pain.—The most dangerous mistake one can make occurs in the patient who, the day before yesterday, had a normal exercise tolerance. Today he developed an acute upper abdominal pain, and is to be operated for an acute surgical abdomen if the medical consultant approves. In this situation, the rules delineated above do not cover the danger, which is, of course, that the "surgical emergency" may actually be an acute coronary thrombosis.

Several years ago a healthy looking milkman of 41 years came to the hospital with belching, vomiting, diarrhea, slight jaundice and acute epigastric pain of recent origin. His temperature was 101° F. The leukocyte count showed 19,000 white blood cells, and the internist in charge suspected a surgical lesion and requested a surgical consultation. Dr. Julian Johnson saw the patient and decided that the abdominal tenderness was insufficient to account for the fever and leukocytosis, and requested an electrocardiogram which showed clear evidence of recent cardiac infarction!

Coronary occlusion often disguises itself very effectively, as it did in this instance, by means of certain unexpected phenomena. It cannot be emphasized too strongly that every "surgical" patient with acute upper abdominal pain must be considered to have had acute coronary occlusion till proved otherwise, especially if the abdominal tenderness is not sufficient to fit a surgical diagnosis.

The Patient with Tachycardia.—If the exercise tolerance is good, there is no major danger to be expected from the heart. The danger is that the patient may have unrecognized hyperthyroidism and may be precipitated into a thyroid crisis by the operation.

The Rheumatic Cardiac Patient with Abdominal Pain.—Abdominal pain is not infrequently a symptom of active rheumatism in such patients. If the indications for operation are not clear, it may be well to watch the situation for a while. However, the distant possibility of active rheumatic fever should not cause you to allow an acute appendix to perforate.

The Patient with Gallbladder Disease(?) or Coronary Pain (?) or

Both.—Problems in this area are some of the most difficult you will be called upon to solve. Common duct distention can produce pain under the sternum and in the arms, which may resemble coronary pain in location and character. However, the experienced clinician can usually differentiate between the two by a careful history and physical examination, especially if he does not conclude that an electrocardiographic abnormality proves the coronary etiology of an acute pain, or that the presence of gallstones indicates that the pain arises from the biliary tract.

Anesthesia.—The problems of anesthesia are quite obviously beyond the scope of the present discussion. However, it might be well to mention two points:

1. The question of *which anesthetic agent to choose*. The competent specialist in anesthesia knows a great deal more than the average internist about answering this question. Consequently it is our practice to discuss with the anesthesiologist the problems presented by the patient, and then to defer to him in the choice of the anesthetic. If an operation *must* be performed on a patient with a serious cardiac problem in the absence of a competent anesthesiologist, it is best to advise the person who will give the anesthetic to use that agent with which he has had the most experience. The skill with which an anesthetic agent is used is apt to be more important in the outcome than the agent itself.

2. In operating on any patient in Group 3 (see above) the anesthesiologist may be more important than the surgeon in bringing the patient through safely. Elective operations should not be performed on such patients unless a competent anesthesiologist is available.

Discussion.—Although we have pointed out that the exercise tolerance is of prime importance in determining the cardiac risk of operation, we do not mean to imply that the rest of the examination should be neglected. Whenever an important decision is made concerning the life and health of a patient, a careful, complete examination is a prerequisite. If evidence of a cardiac lesion is found, you will question him more carefully about his exercise tolerance, and about the possibility of activity of the agent which caused the cardiac lesion. If an electrocardiographic abnormality is found, it may help to call attention to a coronary lesion which was missed, because your history was not taken carefully enough. If hypertension or mitral stenosis is found, the anesthesiologist will watch the patient's circulatory condition during operation with more than usual care. Long experience, and the intangibles of judgment are as important in evaluating the cardiac risk of a surgical patient, as they are in all the other fields involving medical decision. Yet the importance of concentrating attention on the patient's reaction to exercise is worthy of emphasis. Do not let your judgment be clouded by unimportant electrocardiographic anomalies, minor blood pressure elevations, insignificant arrhythmias or auscultatory findings of doubtful significance.

POSTOPERATIVE PROBLEMS

Relatively few serious cardiac problems occur postoperatively in patients whose preoperative evaluation has been accurate.

Tachycardia.—One of the common reasons for an emergency postoperative consultation is the development of a sudden paroxysm of tachycardia (or auricular fibrillation) with a cardiac rate of 160 to 200. This condition must be differentiated from shock or hemorrhage. This can usually be done from the foot of the bed. The patient with paroxysmal tachycardia does not, as a rule, look seriously ill. If you are uncertain, inquire about previous attacks, or take an electrocardiogram. The treatment should not as a rule be heroic. These attacks usually subside spontaneously. Put an ice bag on the precordium. Give the patient a mild sedative and reassure him. Advise a rectal tube and heat to the abdomen or occasionally an enema. Potent medications directed at the heart are usually unnecessary, and may be undesirable.

Acute Attacks of Chest Pain and Dyspnea.—These attacks are apt to be pulmonary in origin (embolus, atelectasis, pneumothorax or pneumonitis) rather than coronary. Postoperative coronary thrombosis, in our experience, is relatively uncommon in the patient without preoperative evidence of active coronary disease.

The Problem of the Patient who "Goes Bad" During the Postoperative Week, with Fever, Tachycardia, Distention and General Debility.—Many surgeons seem to believe that there is an important treatable cardiac problem in such patients which will respond to digitalis. This situation, however, is usually a peripheral circulatory difficulty resulting from shock, hemorrhage, infection, pneumonitis, or intestinal obstruction. I have not observed digitalis to be helpful, unless there was reason to believe that a pre-existing cardiac lesion was present and unless the patient showed signs of congestive heart failure. If the surgeon is insistent, it is usually possible to satisfy him with a small dose of digitalis which will do the patient no harm.

Be sure to advise against excessive administration of intravenous fluids after operation in a patient whose cardiac competence is questionable.

SUMMARY AND CONCLUSIONS

1. The decision as to whether a patient is a good operative risk from the cardiac standpoint depends mainly on two things. (a) How he tolerates the activity of everyday life. (b) Your being absolutely certain, in all patients with upper abdominal pain suspected of having a surgical cause, that a fresh cardiac infarct is not causing the pain.

2. Except in the differential diagnosis of upper abdominal pain where the electrocardiogram is often of great importance, the history is the mainstay. The physical examination should not be neglected but in most

cases it is usually of less importance than the history in making the final decision.

3. The consultation which internists so often receive from their surgical colleagues, "Please take an electrocardiogram on this patient and tell me if it is safe to operate" indicates that the man making the request has not grasped the fundamentals of the problem of evaluating operability from the cardiac point of view

THE SURGICAL PHYSIOLOGY OF THE GASTROINTESTINAL TRACT

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Most of the recent advances in the surgical management of lesions of the stomach and duodenum can be attributed to a better understanding of the normal and pathologic functions of the various portions of the gastrointestinal tract. Probably the surgeons of fifty and sixty years ago knew almost as much about the technic of gastrointestinal operations as the surgeons of today, yet operations in this area, fifty years ago, carried a relatively high mortality, they were uncertain in their results, and cases had to be selected carefully before they were undertaken. In other words, not only has the mortality been reduced but many operations are undertaken now which would never have been attempted at all a few decades ago.

As space is limited, no attempt will be made to consider the lesions of the mouth and pharynx.

ESOPHAGUS

The first lesion that will concern us is *congenital tracheo-esophageal fistula*. This lesion occurs in several forms depending on whether the upper, the lower or both ends of the atretic esophagus communicate with the trachea. Nearly all children suffering from this lesion develop pneumonia and experience has shown that this stems not only from swallowing saliva and other material which collects in the upper stump of the esophagus and spills over into the trachea, but also from regurgitation of gastric contents through the esophagus when the lower segment communicates with the trachea. In most of the early attempts to cope with this lesion surgically, a preliminary gastrostomy was performed. The mortality from aspiration pneumonia continued, and it was not until surgeons learned to close the fistula first and, if necessary, defer the gastrostomy until later, that real progress in this condition was made. It is evident from the studies upon this condition that in babies regurgitation of material from the stomach into the esophagus is frequent.

The next lesions to be discussed comprise a group described variously as *cardiospasm*, *achalasia*, and *congenital shortening of the esophagus*. In the past, it has been customary to dilate constrictions at the cardia

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through the esophagoscope, or preferably by the use of a retrograde bougie after gastrostomy has been performed. In this way, it has frequently been found to be a safe and effective method of maintaining the patent for feeding of the pathway for gastrostomy.

A number of operations have been suggested to relieve this condition. One of the simplest, which can be performed transthoracically, is to draw the fundus of the stomach up through an opening in the diaphragm and do a side-to-side anastomosis between it and the esophagus above the lesion. Recently, Wangensteen¹ has postulated that most of the disease in this area may be due to the regurgitation of gastric contents into the esophagus with ulceration and scarring. He has stated that, with the exception of the duodenum, the lower end of the esophagus is more subject to peptic ulceration than any part of the gastrointestinal tract. He has applied this hypothesis in practice and has, in a small group of cases, resected the lower portion of the stomach (about 80 per cent) so as to reduce the amount of acid formation which occurs. His results to date have been very satisfactory in that cardiospasm and achalasia have been relieved and the patients have been able to take food by mouth. A somewhat longer period for follow-up will be required before final conclusions can be drawn with regard to the validity of Wangensteen's hypothesis.

THE STOMACH

Gastric Secretion.—A very large amount of work has been done on the physiology of the stomach and some of the earliest observations were made on a patient named Alexis St. Martin, by the early American army surgeon, William Beaumont. Alexis St. Martin had a gastrostomy

digestive material.

The experiments of Pavlov on the conditioned reflex demonstrated the control of gastric secretion exercised by the central nervous system. This is, of course, one of the bases for vagotomy, the therapeutic measure revived by Dragstedt and vigorously advocated by him during recent years in the treatment of duodenal ulcer. A gastric pouch with an external opening constructed so as to preserve the vagus nerve supply to its wall still bears Pavlov's name.

It is known that, in addition to the cephalic phase of gastric secretion, there is also a gastric phase and an intestinal phase. Thus secretion is stimulated by food in the stomach and by food and the products of its digestion in the intestine. Mechanical irritation of the gastric wall is probably a weak stimulus to secretion also. Edkins first described a

substance which he prepared by grinding pyloric mucosa with certain foodstuffs that would stimulate gastric secretion when injected intravenously (gastrin). It is now believed (Best and Taylor²) that the active material in such preparations is histamine. It has been shown that it can be derived just as well by using mucosa from the fundus of the stomach, so that insistence upon removal of all of the gastric antrum when partial gastrectomy is performed can no longer be based upon the earlier belief that the gastric phase of gastric secretion was mediated through this area. However, most surgeons persist in this practice because it seems unwise to leave gastric mucosa in a situation where its secretions can only be neutralized by reflux of duodenal contents through the pylorus. Such segments are presumably stimulated during both the gastric and intestinal phases of secretion. How much acid they secrete in man is not known.

The intestinal phase of gastric secretion is also due to a humoral mechanism. Whether any humoral agent other than histamine takes part in either the gastric phase or the intestinal phase remains uncertain.

Enterogastrone, an active principle derived by Ivy and his associates from the intestinal mucosa, has the effect of suppressing gastric secretion and gastric motility.

Gastric Acid Formation.—The last few years have made available much basic information with regard to the secretory function of gastric cells, particularly in connection with acid formation. Interestingly enough, this seems to have developed, in no small measure, from studies on the electrical currents formed in the stomach which began fully sixty years ago by Bohlen. The recent work in Krieb's laboratory, by Crane, Davies and Longmuir,³ is perhaps the most convincing of the recent papers on this subject because these authors worked with isolated segments of frog stomach. When such segments are mounted as a diaphragm dividing a vessel into two separate chambers, secretion can be maintained for several hours by supplying suitable media and by bubbling oxygen through the fluid exposed to the serosal surface. Such segments of mucosa may be stimulated to active secretion by histamine, or their secretory activity may be inhibited by atropine. The mucosal surface develops an electrical potential difference in the neighborhood of 40 millivolts and is negative to the serosal surface. This potential difference is maximal when gastric secretion is inhibited, and is reduced to a lower level, but not zero, when gastric secretion is stimulated. Both gastric potential and acid formation may be reduced to zero by withdrawing the oxygen supply, and if this oxygen supply is restored after a brief interval, secretion may be resumed and the potential will again appear. The reduced electrical energy in an external circuit which occurs when secretion is stimulated by histamine is believed to be roughly proportional to the chemical energy represented by the hydrochloric acid formed. This work confirms earlier observations of Rehm⁴ made in the stomach of the dog.

It is probably significant that Stout notes a reduction in the oxyntic or acid-forming cells of the gastric mucosa, both in carcinoma of the stomach and in atrophic gastritis. How this reduction is brought about is not clear but it would seem to be consistent with the reduced acid formation so often noted upon gastric analysis in patients with carcinoma of the stomach. It would also seem to correspond with the inability of the stomach containing a carcinoma to give a normal electrical response after the ingestion of milk. This latter phenomena was first observed by Goodman⁵ in 1942. Additional data has recently been obtained and analyzed by Sawyer, Rhoads and Panzer.⁶

Several studies have shown that the pH of the material secreted by gastric acid-secreting cells is relatively constant and is very close to a pH of 1 (Hollander⁷). The material obtained by aspiration of the stomach varies considerably because of an admixture of mucus and other buffering material.

Experience has shown that one-half or two-thirds of the stomach can be removed, and yet that secretion from the remainder will be so copious and will contain so much acid as to produce stomal ulcers. If, however, 75 to 80 per cent of the stomach is removed, this will rarely occur. An exception has recently been reported by Machella and Rhoads⁸ in which such a resection proved inadequate and the patient was restored to health after total gastrectomy.

Gastric Emptying.—In addition to the information which has been presented on gastric acid formation, there is a good deal of data of clinical significance regarding gastric emptying. One of the earliest of the enigmas encountered in gastric surgery was the persistent vomiting which sometimes occurs after gastroenterostomy. For some decades, this was referred to in surgical literature as vicious cycle or vicious circle.

basis for this belief and I have by means of the fluoroscope observed barium to follow this route in one patient. Surgeons have, at times, re-operated on such patients to inspect the gastroenterostomy and to see that there was no technical defect. They would then divide the stomach across the pylorus to break the circle. As early as 1929, Ravdin obtained evidence that one factor in producing this complication was *hypoproteinemia*. In an important paper in 1933 on the occurrence of edema in surgical patients, Jones and Eaton⁹ called attention to a series of patients in which this had occurred when excessive saline had been administered parenterally.

In 1937, Meccray, Barden and Ravdin¹⁰ published the results of a study in dogs which indicated by controlled experiments that hypoproteinemia would interfere with gastric emptying after gastroenterostomy and gastric resection, in that species, and furthermore, that it had a profound effect upon the emptying of the unoperated stomach in the dog. The relationship between the serum protein concentration in grams

per hundred milliliters and the gastric emptying time for water barium meal in hours is an inverse one. In our clinical experience, subsequent to this work, hypoproteinemia has been by far the most common cause of delayed gastric emptying. There are, however, other factors. That vitamin B deficiency may have a similar effect was demonstrated by Heublein and his associates¹¹ in 1941. It is often possible to differentiate this effect from that due to hypoproteinemia roentgenologically. In hypoproteinemia, not only is the gastric emptying time delayed, but transport of the barium meal from the stomach to the cecum is also retarded. In vitamin B deficiency, on the other hand, stomach to cecum time is reduced, in spite of the fact that gastric emptying is delayed.

There would seem to be little doubt that *trauma in the region of the anastomosis* may, at times, be a factor in delayed gastric emptying in the immediate postoperative period. In our experience, open anastomoses have more frequently worked satisfactorily during the early postoperative period than have anastomoses performed with clamps. At times, clamps exert such pressure on the gastric wall as to practically destroy the mucosa in the area where they are applied. If this be close to the stoma, as when three blade anastomosis clamps are used, the factor of local trauma may be a serious one.

Gastric emptying is profoundly affected by the *nature of the test meal*. In general, it may be said that fat exerts a retarding influence on gastric emptying, and that hypertonic fluids usually are not emptied until they are sufficiently diluted to be at or close to isotonicity. Thus, Johnston and Ravdin¹² injected hypertonic glucose into the stomach of dogs and determined the concentration of the material as it reached the duodenum and the proximal jejunum. It was found that the concentration entering the small bowel was seldom above 5 per cent (which is approximately isotonic).

The late Dr. W. Osler Abbott and his associates¹³ confirmed these findings in man. He was able to recover intestinal content at various levels by the use of the Miller-Abbott tube and found that the human stomach, like the dog's, diluted hypertonic glucose and only discharged it into the small bowel when it was at or close to isotonic levels.

These studies have important bearing on a number of clinical problems. In making x-ray evaluations of gastric emptying, any deviation in the test meal from the standard water barium mixture cannot be evaluated except in the light of an extended experience with the particular preparation used. In the second place, the observations cited afford an explanation for the diarrhea so commonly encountered with jejunal feedings. This seems to be true regardless of whether an external jejunostomy has been done or whether the nutrient mixture is placed in the jejunum by means of an Abbott-Rawson tube, either by the orojejunal method of Stengel and Ravdin,¹⁴ or by the gastrojejunal method as suggested by Bisgaard. Most of these nutrient mixtures contain sugars or other relatively small molecule foods and, when these enter the jejunum, their osmotic force results in a considerable outpouring of

fluid from the jejunal wall. This apparently has somewhat the effect of a saline cathartic, in many of these patients, and often results in quick diarrhea with loss of much of the nutrient mixture.

The "Dumping Syndrome".—Machella¹⁵ has recently shown that the "dumping syndrome," which is seen from time to time after gastro-jejunosomy, is probably related to the osmotic effect of meals which are quickly transferred from stomach to small bowel. Much has been written

tant. Neither elevation or reduction of this level by parenteral means induces the symptoms of dumping syndrome in subjects who suffer from it. When their symptoms are produced by a suitable meal, containing a considerable amount of glucose or saccharose, it is generally found that the blood sugar rises shortly after the ingestion of the meal and frequently this rise takes place close to the time that symptoms are observed. He has been able to reproduce the symptoms by injecting concentrated solutions directly into the jejunum by way of a tube passed through the gastroenterostomy. Indeed, symptoms of great severity have been produced in this way. He has also reproduced the symptoms by placing a balloon in the jejunum, just beyond the stoma, and inflating it. It would seem, therefore, that dumping syndrome occurred when the stomach emptied too promptly, discharging a meal which has not been properly diluted into the jejunum. The meal, upon reaching the jejunum, immediately draws in excessive amounts of water and this, in turn, causes distention of the bowel with a rise in pulse rate and blood pressure and often abdominal pain and sweating.

It is of interest to note that occasional patients with dumping syndrome will have diarrhea and that occasional patients who have diarrhea

not yet evident. Most stomas are made 3 cm. or more in length, so that the stoma is probably wider than the diameter of the efferent loop. There is little experience with the use of really small stomas. In one severe case of dumping syndrome, however, we reduced the size of the stoma by nearly 50 per cent with resulting improvement in the patient's symptoms.

the stomach dilutes it to a digestion is begun by the action of pepsin and hydrochloric acid. The acid kills a majority of ingested micro-organisms so that gastric contents in the presence of normal acidity are relatively sterile. When this acidity is lost, however, due to any cause, the flora of the stomach increases as various bacterial forms not commonly found in gastric juice appear,

and the risk of peritonitis, when such a stomach is operated on, is considerably increased. Usually, however, with the prophylactic use of the antibacterial agents now available, this does not become a serious problem. Harvey and Oughterson have suggested gastric lavage with suitably dilute solutions of hydrochloric acid in patients with anacidity as a preparation for operation.

THE SMALL INTESTINE

The Physiology of the Small Intestine.—A number of the functions of the small intestine have already been discussed in connection with functions of the stomach in the presence and in the absence of gastroenterostomy. One of the major functions of the small intestine is, of course, transport of material between the stomach and the large bowel. The late Dr. W. Osler Abbott¹⁶ investigated the pressure gradient in this segment of the bowel by the use of the Miller-Abbott tube. In most of these studies, the balloon was connected to a manometer and a recording of pressure changes in the balloon was made on a kymograph. The pressure on the balloon is, of course, constantly changing with movements of the bowel wall. In addition to the more or less purposive downward peristaltic movements of classical physiology, Abbott also described segmental movements of the bowel which he believed to have a function in mixing the contents and not to be concerned with their transport. In general, the pressure in the duodenum was the highest of any level of the small bowel and the pressure gradually decreased all the way down to the ileocecal valve. It was Abbott's

endency for the semiliquid material within the bowel to move in the direction of the lower pressure which was normally at the ileocecal valve.

In mechanical obstruction of the small bowel, Abbott suggested that fecal vomiting encountered was not due to reverse peristalsis, but to a reversal of the pressure gradient. In this situation, the pressure commonly became higher close to the obstruction, with the result that the movements of the bowel wall resulted in a back flow of material toward the upper portion of the small intestinal tract. It was his observation, and that of Johnston, that suction syphonage through a Miller-Abbott tube quickly stopped fecal vomiting and, as the tip of the tube lowered the pressure in the proximal bowel, such peristalsis as there was tended to carry the balloon and the tip of the tube downward. In this way, successive loops of distended bowel would be decompressed until the tube and balloon finally reached the point of obstruction. This series of observations, of course, provided the physiological basis for the use of the Miller-Abbott tube in intestinal obstruction.

It has long been known that obstruction of the small bowel is less well tolerated than is obstruction of the large bowel. Formerly, it was supposed that this was due to the early vomiting which occurred with small

bowel obstruction, and the resultant electrolyte imbalance. While this

of peripheral circulation. An explanation for this was reported by Gendel and Fine¹⁷ who showed in 1940 that marked plasma volume changes come on rapidly after the small bowel is obstructed in animals. The loss of plasma occurs into the bowel wall and perhaps, to a less extent, into the lumen of the intestine and into the peritoneal fluid. Presumably, the tension on the bowel wall obstructs venous return and increases capillary blood pressure with the resulting loss of fluid and some protein. Whether or not this is the explanation, plasma may be rapidly lost with small bowel obstruction. Whereas, large bowel obstruction, under similar conditions, results in much smaller losses. Simple decompression of distended small bowel will usually lead to restoration of a considerable portion of the plasma volume deficit.

The Digestive Function of the Small Intestine.—As food makes its way through the alimentary tract, it first meets amylase in the saliva, then hydrochloric acid, pepsin, rennin and gastric lipase in the stomach, and then in the duodenum and upper jejunum it is attacked by a variety of enzymes. The pancreas provides several: amylase, trypsinogen, steapsin, and chymotrypsinogen and pancreatic lipase. The secretion of the intestinal wall or succus entericus, as it is called, provides enterokinase which activates the trypsinogen to trypsin and erepsin and peptidase, as well as ferments for lactose, sucrose and maltose. The liver supplies bile, containing lipase and traces of amylase and, in the normal individual, bile salts often concentrated five to ten times in the gallbladder and discharged by the contraction of the gallbladder in

of these various digestive juices is believed to range as high as 7 liters per day. It is uncertain how important a role salivary amylase plays. There are children with strictures of the esophagus, fed by gastrostomy, who have to expectorate all of their saliva, who frequently do much better if the saliva is collected and re-fed. This, however, may be more a matter of fluid and electrolyte balance than of actual digestion.

Pepsin is necessary for the preliminary splitting of certain types of proteins. After it has done its work, trypsin and enterokinase from the bowel wall are further able to digest proteins. It is not clear at what level of hydrolysis most proteins are absorbed but it is believed that a portion are broken down to amino acids and other portions absorbed as polypeptides. Fat is at least partially reduced to fatty acids. Some of it is absorbed by way of the lacteals and the lymphatic system. Carbohydrates are reduced to dextrose and levulose and may be absorbed as such.

Digestion is a relatively efficient mechanism in the normal individual.

Ingested food proteins are often absorbed to the extent of 95 per cent, fats to the extent of about 90 per cent, and carbohydrates to the extent of 95 per cent, or higher. The major portion of this absorption is said to take place in the upper 5 feet of jejunum and duodenum. Little absorption takes place in the stomach except in the case of glucose and alcohol which require no chemical processing. A great variety of disturbances may occur in the digestion of foods. The rapid transit through the small intestine with expulsion of much nutrient material is seen as the result of improper dilution of nutrient mixtures before they reach the small bowel. The result is not unlike that seen in gastrojejuno-colic fistula, where much of the food may proceed directly from the stomach to the colon and be excreted with little change.

In various forms of pancreatic disease, the enzymes derived from this organ are deficient or totally lacking. The failure of fat digestion is most prominent and the stools become fatty and foul smelling. They usually are quite soft and both numerous and bulky. Nutrition is impaired, not only because half or more of the fat is lost in the stool, but because 25 to 35 per cent of the protein, and also some of the carbohydrate, often passes through undigested. (See Chapter on Surgical Lesions of the Pancreas in regard to management of patients of this type.)

The permeability of the wall of the small intestine to electrolytes is apparently high. Lavage of the intestine with plain water will remove considerable amounts of sodium, chloride and other ions, and Abbott found that the average chloride concentration of material withdrawn from a Miller-Abbott tube was about two-thirds that of physiological saline. There is, therefore, a real danger of rapidly producing hypochloremia when a patient is continued on suction siphonage of the small intestine for considerable periods of time. In one patient, studied by Walker,¹³ who had a high small bowel fistula, the chloride losses within certain twenty-four hour periods amounted to over 40 per cent of the total chloride normally present in the extracellular fluid. The treatment of high small bowel fistula is to a very large extent one of water and electrolyte replacement and until a good deal of progress in this field was made, duodenal fistulas were almost always fatal. Now they seldom prove fatal but they always require intensive care. In addition to the supportive treatment required, continuous suction to the fistulous tract has proved of great value.

THE LARGE BOWEL

The colon may be thought of as having dual functions—*reabsorption* of fluid and storage of feces. It is capable under certain conditions of absorbing some nutrient material.

The right side of the colon is the portion chiefly concerned with the recovery of the large volume of water and electrolytes poured into the gastrointestinal tract by the various glands concerned with digestion. When one considers the extent of the sodium chloride loss, measured by

Walker¹⁸ in small bowel fistulas, it is evident how important this function is. It follows that a patient with an ileostomy for ulcerative colitis is in a highly unstable condition. We have seen certain of these patients who required exceedingly large volumes of parenteral fluid until they were able to stabilize themselves. Stabilization seems to occur by change in the functions of the terminal ileum so that the discharge from it becomes somewhat thicker and less watery. How this change in function is mediated is not known.

The left side of the colon seems to function more as a storehouse for
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 is not surprising that mechanical obstruction is more common in this area. This may, however, be due to the fact that carcinoma, which is the common cause of large bowel obstruction, characteristically assumes a constricting annular form of growth in the left colon, whereas, it is more apt to appear as a mushroom adenomatous type of growth in the right colon. Whether there is anything specific in the production of anemia in cases of cancer of the right colon, or whether this is merely the result of the chronic loss of small amounts of blood, remains obscure.

The greater diameter of the cecum apparently makes it more vulnerable to perforation in chronic obstruction of the large bowel. Its susceptibility to distention may also account for the frequency with which pain is felt in the cecal region in patients with obstructing lesions of the large bowel at any level.

When the ileocecal valve is competent, so that material from the cecum cannot regurgitate back into the ileum, an obstructing lesion in the colon is believed at times to result in a so-called "closed loop" obstruction with proportionately greater severity of symptoms.

The absorptive powers of the large bowel were extensively relied upon by clinicians of fifty years and more ago. Many so-called nutrient enemas containing milk, eggs and other foods were administered to patients who could not take food by mouth satisfactorily. Edsall and Miller, and others, condemned this practice and Edsall and Miller¹⁹ showed by analysis that such foods were largely returned in subsequent bowel movements.

That the large bowel is capable of absorbing certain types of food was shown, however, by later experiments. Folin²⁰ showed that certain amino acids and Witte's peptone, when placed in the freshly isolated large bowel of the cat, resulted in a rise in some of the nonprotein nitrogen constituents of the blood. Abderhalden and Schittenhelm²¹ were able to maintain nitrogen balance in a human subject largely by rectal feedings of a protein hydrolysate. In a study in chronically isolated large bowel loops in the dog, Rhoads and his associates²² were able to show that about 30 to 35 per cent of the nitrogen in hydrolyzed protein was absorbed within two hours from such a loop and that the absorption was not confined to amino acids but included large products of protein

hydrolysis in substantial amounts. The large bowel is also capable of absorbing glucose but, according to the studies of Ebeling,²³ the amounts absorbed in this way are quite small.

Now that the intravenous route has been developed to a point where both glucose and certain protein derivatives can be administered so readily, there is little occasion to employ the rectal route with the uncertainty of retention which is encountered in many patients. However, it is well to keep it in mind for the rare patient who has very frequent pyrogenic reactions after intravenous therapy.

SUMMARY

Certain physiological data on gastro-intestinal motility, hydrochloric acid secretion, water and electrolyte exchange across the gastrointestinal mucosae, and food absorption, have been considered in relation to surgical management.

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SURGICAL PHYSIOLOGY OF BOWEL OBSTRUCTION

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A consideration of intestinal obstruction and its related abnormalities concerns not only a particular anatomic area per se, but also it encompasses and is an intimate part of all intra-abdominal disease. Although fundamentally the problem of intestinal obstruction relates to an abnormality of intestinal transport, the causes of such interference are many and varied. They may be purely mechanical or they may be on the basis of congenital deformity, nervous imbalance or intraperitoneal infection. Nevertheless, the clinical picture of acute mechanical obstruction is usually a clear and sharp one, its symptoms, physical findings and x-ray appearance are characteristic, and the diagnosis should not be a difficult one to establish. In the light of present knowledge it is possible to outline therapeutic principles which if applied promptly, wisely and skillfully, should result in the vast majority of cases in a gratifying outcome to both patient and surgeon. In essence, therapy should be directed to the correction of nutritional, fluid and electrolyte disturbances, relief of distention, release of the obstructing mechanism and the removal of devitalized bowel with the restoration of intestinal continuity.

During the past century a voluminous literature on intestinal obstruction has accumulated. Excellent monographs by Treves³⁶ in 1899, McIver²⁷ in 1934, and Wangenstein²⁷ in 1942 present this accumulated literature in a clear, concise and readily available manner.

Normally there enters into the upper intestinal tract of man about 7000 cc. of fluid secreted as follows: (1) saliva, 1000 to 1500 cc., (2) gastric juice, 2000 to 3000 cc., (3) bile, 300 to 500 cc., (4) pancreatic juice, 500 to 800 cc., and (5) succus entericus, 1000 to 3000 cc. Most of this fluid is re-absorbed in its passage down the small intestine, since it has been estimated that only about 400 cc. daily pass the ileocecal valve into the colon.

Physiologic alterations resulting from or attending obstruction to the normal passage of material down the intestinal tract relate chiefly to (1) the local and systemic effects of fluid and electrolyte losses, (2) the effects of distention on the function and viability of the gut, (3) toxic factors associated with intestinal obstruction, (4) the relation of bacterial growth to intestinal viability, and (5) the problems attending compromise of blood supply of the intestine.

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FLUID AND ELECTROLYTE LOSSES

In 1912 Hartwell and Hoguet¹¹ observed that dogs with complete obstruction in the lower duodenum lived for only a few days if untreated. If, however, they administered subcutaneously daily a quantity of normal saline solution equal to the amount of water lost by vomitus and urination, their dogs promptly improved and returned to the condition of dogs undergoing simple starvation. Their dogs so treated lived in good condition for three weeks or more. Unaware of the fundamental electrolyte imbalance they had corrected, they felt that the cause of death of high intestinal obstruction was due to dehydration brought on by vomiting.

The work of Haden and Orr^{12, 13} in 1923 demonstrated a fall in blood chlorides followed by alkalosis as a result of loss of gastric juice due to vomiting. However, it was the work of Gamble and Ross¹⁴ in 1925 that clarified the pattern of electrolyte and water loss in high obstructions and explained the beneficial effect of saline administration. They showed that the withdrawal of electrolytes from the body fluids was accompanied by a proportional reduction of body water and that this change could only be reversed and corrected by replacing both the lost water and lost electrolyte. Five per cent glucose solution alone would not sustain the normal volume of body fluids in the presence of continued loss of electrolyte. It was this extreme dehydration in high intestinal obstruction that resulted in severe prostration and rapidly led to a fatal outcome, which earlier workers had almost uniformly ascribed to a toxic factor found in the lumen or mucosa of the obstruction bowel. Gamble and associates felt that loss of Na^+ was the essential factor in the rapid dehydration that occurred.

Sodium ion may be lost directly in the vomitus. In addition, however, with a preponderant loss of Cl^- , as occurs in high obstruction, an alkalosis develops which is compensated for by an increase of the HCO_3^- ion in the serum. Because of the alkalosis there is an increased excretion of base (Na^+) in the urine, further depleting the total base of the body. Loss of Cl^- ion can be temporarily compensated for by mobilizing HCO_3^- from metabolic stores, but the loss of base (Na^+) results in a contraction of the extracellular compartment of the body (dehydration). The increased levels of serum nonprotein nitrogen and urea nitrogen commonly seen in obstruction of considerable duration is a sequel of severe dehydration with extra renal suppression of urine formation. More recently as a result of the work of Darrow,¹⁵ it has become apparent that the intracellular water compartment also appears to play a role in dehydration states. Under these conditions further depletion of Na^+ may take place by its diffusion into the cells, replacing the K^+ which is normally the predominant intracellular cation.

In humans the losses of fluid and electrolyte accompanying high intestinal obstruction may at times appear almost astronomical. The author recently observed a 44 year old man who had become obstructed

at the efferent stoma of a short loop gastroenterostomy which had been performed elsewhere some eight years previously. This man lost daily in measured gastric aspiration from 7000 to 8800 cc. of intestinal content consisting, no doubt, of all of his saliva, gastric juice, bile pancreatic juice and duodenal succus entericus. In order to maintain adequate hydration it was necessary to administer parenterally to this individual from 10,000 to 11,000 cc. of fluids daily containing from 45 to 50 gm. of sodium chloride.

The amounts of fluid lost by vomiting, the chemical composition of the fluid lost and the resultant blood chemical profile of the patient will

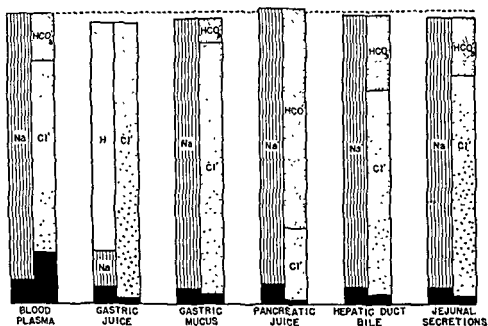


Fig. 608 —Electrolyte composition of gastrointestinal secretions. (From *Pathology of Extra-intestinal Obstruction*, W. B. Saunders Medical School, 1939.)

vary with the site and level of the obstructing process. Figure 608 shows the relative electrolyte profile of the various gastrointestinal secretions. Aside from gastric juice where there is a preponderance of Cl^- and pancreatic juice where there is a preponderance of Na^+ , the relative concentrations of Na^+ and Cl^- are about the same. Such being the case, the obstructions below the gastric outlet are not so prone to develop the alkalosis seen in pyloric obstructions but will nonetheless show the effects of dehydration and total salt loss. However, the higher in the intestinal tract the obstructing mechanism resides, the more profuse and copious is the vomiting. In low obstructions, where vomiting ordinarily is less profuse, but where large quantities of intestinal content may accumulate in the distended coils of intestine, dehydration may still occur. In the rabbit, which cannot vomit, obstruction causes the same

characteristic blood changes of dehydration and decrease of total plasma electrolyte

On the other hand, in low intestinal obstruction the administration of adequate water and electrolyte fails to evoke the dramatic response that attends their use in high obstruction. Under these circumstances there

succeeds in preventing great distention. Hence, under these circumstances the predominant ill effects of obstruction relate principally to the loss of fluid and electrolyte incurred by vomiting. In lower small bowel obstructions, which are the most frequent clinically, the mechanical effects of distention on the bowel are every present, and they tend to dominate the pathologic picture that is presented.

DISTENTION IN INTESTINAL OBSTRUCTION

Distention of intestinal loops by gas or mixtures of gas and fluid is a constant accompaniment of intestinal obstruction. Early in the course of the obstruction the distention is chiefly gaseous and results in the characteristic x-ray picture of small bowel obstruction. Past the period of infancy (three years) in healthy individuals, one does not normally see gas in the small intestine on x-ray examination. Obstructions of longer duration show greater quantities of fluid accumulated in the intestinal loops, and the gas may not appear as conspicuously. Occasionally cases are encountered having distended loops of bowel containing principally fluid, so that on routine flat x-ray film examination these dilated loops may not be apparent. Such an error can be avoided if upright films are also taken, in which case fluid levels become evident in small intestinal loops showing the admixture of gas and fluid.

Distention per se is a serious manifestation of intestinal disease, and if prolonged for any considerable period it can initiate mucosal degeneration evidenced by petechial hemorrhages, erosion and ulceration. Moreover, long continued distention can so compromise intramural blood flow as to endanger the viability of the bowel. Systemic effects of distention may also be of considerable moment and cause marked discomfort to the patient.

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shown, there may be interference with venous return from the lower extremities.

Sources of Gas in the Bowel.—Three possible sources of the gas in bowel obstruction are apparent: swallowed air, gas formed locally in the bowel as a result of chemical action or bacterial putrefaction and fermentation, and diffusion of gas into the gut from the blood stream

Swallowed Air.—McIver^{23, 29} in 1926 observed that the gas in the stomach after operations was largely swallowed air. In addition, he

showed that air injected into the stomach of animals often passed downward into the intestine. Animals with peritonitis in whom the pylorus was ligated so that air could not pass into the intestine showed a dilatation of the stomach but no distention of the intestines. When the pylorus was not ligated, on the other hand, dilatation of both stomach and intestine occurred, indicating passage of air downward from the stomach. He also noted that when O_2 was injected into a closed loop of intestine, there was not only absorption of O_2 out of the loop by the blood stream, but also diffusion of N_2 and CO_2 into the loop from the blood stream.

Hibbard,²² studying the gases of mechanical small intestinal obstruction, concluded that about 72 per cent of the gases present were derived from swallowed air. The amount formed within the body was 28 per cent and, of this, 70 per cent originated from diffusion of the gases, dissolved according to their partial pressures in the blood, into the lumen of the bowel, and the remaining 30 per cent resulted from decomposition of food materials locally within the intestinal lumen.

A further definition of the role of swallowed air in producing intestinal distention in obstruction is well brought out by the experiment reported by Wangenstein and Rea.²³ In these animals a cervical esophagostomy was performed whereby the proximal esophagus was brought out as a cutaneous salivary fistula, thus preventing swallowing. A complete obstruction was then produced at the terminal ileum. By thus precluding any possibility of swallowing air, these animals sustained by parenteral fluids survived on the average 35.2 days, with the longest surviving for 57 days. At death the intestines were empty and collapsed. By excluding the factor of swallowed air it was possible for the obstructed intestine to absorb the gastric secretions, bile, pancreatic juice and succus entericus without producing distention. For the most part, these animals lived about as long as a normal dog would live if deprived of food and sustained on subcutaneous water and salt alone. A controlled group of animals with similar ileal obstructions alone lived five days. Anderson and Ringsted (1943),² studying gas analyses from clinical material, concluded that the gas accumulations in bowel obstruction was due exclusively to swallowed air.

Other Sources.—In the presence of obstruction and with gaseous distention established, there accumulates large amounts of foul, fecal-smelling, yellowish fluid. This is the residual of all the intestinal juices mentioned earlier which, because of the distention and obstruction, have failed to be absorbed. In addition, under these circumstances there is an abundant outpouring of secretion by the intestine itself as a sequel of irritation and distention. In this connection the report of Herrin and Meek²² is most pertinent. These authors produced distention by distending balloons in Thiry-Vella fistulas and observed, as a result of the distention, a marked increase in secretion containing a high content of Cl^- ion. Gatch,^{15, 16} on the other hand, felt that secretion may be depressed with elevated intra-enteric pressures of 10 to 15 mm. Hg.

Compensatory Adjustments to Distention.—The normal mechanisms

for transport and removal of gas from the intestinal tract are essentially three. One mechanism is expulsion from the anus at periodic intervals, second is by vomiting and belching; the last is absorption of these gases by the blood stream in amounts according to their partial pressure solubility ratios. Under conditions of obstruction, peristalsis is unable to carry gas beyond the obstructing mechanism, and passage by rectum ordinarily does not occur. Clinically the resumption of passage of gas by rectum is an excellent sign of release of the obstructing mechanism. Removal of the accumulated gas via the blood stream does not suffice ordinarily. Fine¹² and associates have suggested a means of augmenting this transport, however, by the inhalation of 95 per cent O_2 . Under these conditions the plasma does not become saturated with N_2 from the pulmonary alveoli and is able in its passage through the intestinal vessels to absorb and transport away a greater amount of N_2 from the intestinal lumen.

Effects of Distention.—Locally, acute distention of the bowel causes *contraction of its longitudinal muscle with considerable shortening* (Sperling, 1938)²⁴ and an *increase in weight*. The weight per foot of the small intestine normally decreases from duodenum to terminal ileum. In simple ileac obstruction, however, there is a reversal of this normal gradient of weight so that the weight of the bowel immediately proximal to the obstruction is highest, with a progressive decrease occurring in a retrograde direction. Edema of the intestinal wall accounts for only 7 per cent of the increase of weight. An increase of blood, principally due to stasis in the veins, seemed to account for most of the increase of weight (Carlson and Wangenstein, 1932)⁸.

Changes in bursting pressure of the ileum were observed by Sperling and Wangenstein (1935)²⁵ to be most prominent in the segment immediately above the obstruction, where generally it was found to be lower than the normal gut by about 50 per cent.

The *contractile power* of the bowel is augmented and stimulated by mild distention, but when it becomes extreme and prolonged, as Brandberg⁶ noted, there results a decrease in intestinal activity. Sperling (1938)²⁴ observed in dogs that loops of small intestine subjected to pressures from 20 to 100 cm of water showed at first increased peristalsis which then disappeared with fatigue. After a period, peristalsis reappeared, thus completing a cycle of alternate activity and rest. This phenomenon seemed to correspond to the intermittent cramplike pains that characterize bowel obstruction clinically.

Absorption of water from an obstructed loop of ileum was found to be considerably diminished (Wangenstein, 1942).²⁷ Whereas a normal loop absorbed in one hour 87 per cent of the water instilled within it, the obstructed loop absorbed only 9 per cent. On the other hand, increases of intra-enteric pressure to the extent that cause venous stasis result in increased absorption by the lymphatics.

Burget⁷ and associates working with closed jejunal loops in dogs found that they could keep their animals alive and healthy almost indefinitely

as long as they prevented distention by aspirating the loops. When they allowed the loops to distend, there were obvious signs of illness. Histologic studies of aspirated loops were normal, whereas in the distended loops necrosis and perforation were observed.

Gatch and associates¹⁵ and also Dragstedt and associates¹¹ studied the effects of distention on the *circulation* and found that the blood flow decreased with increase of intra-enteric pressure. Dragstedt felt the duodenum to be most susceptible to this effect, in that interference with blood flow occurred there at lower pressures than in ileum or colon. Such a circumstance first results in venous stasis, increased venous pressure, and then increased capillary pressure followed by increased capillary permeability. From the serosal surface edema fluid passes into the peritoneal cavity, producing the clear peritoneal fluid regularly seen with nonstrangulated bowel obstruction. From the mucosal surface also, increased amounts of fluid pass into the lumen. By this means large amounts of protein are lost from the available protein pools of the body. Patients with chronic obstructions and those having endured distention of considerable duration, clinically exhibit the effects of chronic protein depletion.

Some degree of protection from the effects of increased intra-enteric pressure is afforded the gut by virtue of its distensibility and ability to compensate for the increased pressure. However, as Wangenstein points out, the tension on each square centimeter of surface of the bowel is a function of the diameter as stated in the formula $T = \pi DPr$ (T =tension, D =diameter, Pr =pressure). Thus for equal pressures the tension on the surface is greater as distention occurs. A common example of such a circumstance is seen in large bowel obstructions. When perforation occurs, because of failure to decompress the obstruction, it happens most commonly in the cecum where the diameter is greatest, and hence the tension on the surface is greatest. Sperling (1938)¹⁴ found in dogs a definite relation between the height of intra-enteric pressure and the degree of pathologic change occurring after distention. Petechial hemorrhages were apparent after sustained pressure of 10 cm. of water for twenty-four hours. At 20 cm. of water, necrosis, loss of viability and abnormal permeability of the gut wall were observed. These pressures were not far above those measured in clinical bowel obstructions where pressures from 4 to 18 cm. of water were observed, and which rose to 20 to 30 cm. of water with peristaltic activity.

TOXEMIA

The concept that absorption of toxic material from the intestinal lumen was a prime factor in the fatal outcome has been held by writers on the subject since the paper of Amussat in 1839.² This has always been an appealing thought, since it has been appreciated for a long time that obstructed fluid is toxic when injected into other animals and that removal of obstructed fluid by enterostomy is often lifesaving. Also, to support this concept is the clinical appearance of the patient with ad-

vanced obstruction who presents the classic facies of dehydration, malnutrition and toxemia. With the demonstration by Hartwell and Hoguet,¹³ and Gamble et al.,¹⁴ that loss of fluid and electrolyte was the cause of death in high intestinal obstruction, the theory of toxemia had to be abandoned in those cases. Proof for or against absorption of toxins occurring in simple mechanical lower intestinal obstruction is more difficult to obtain. The demonstration that toxic material is present in the fluid of obstructed intestines, and that injection of this fluid or extracts of it into animals results promptly in their death, does not establish that this toxic material can pass the barrier of a viable mucous membrane. Similar toxic substances can be demonstrated in normal intestinal fluid. However, with loss of viability of the intestine, as occurs in strangulation and possibly after marked sustained distention, transmural passage of toxic substances into the peritoneal cavity and absorption by this means may well occur. It seems unlikely that, in the presence of viable intact mucosa, absorption of toxic material from the intestinal lumen takes place.

ROLE OF BACTERIA

In the presence of obstruction the bacterial count of intestinal content increases markedly. Before the era of modern antibiotics, spillage in the course of an operation for obstruction of as much as one drop of intestinal content would commonly prove fatal. Today with better weapons on hand to combat infection, such minor spillage may be better tolerated.

Harper and Blain¹⁵ have suggested that bacterial growth may play a more important role as a cause of death in experimental obstruction than has hitherto been appreciated. Working in dogs and using 12 cm. closed isolated jejunal loops, they observed an average survival time in their control animals of three and one-half days. By instilling penicillin solution into the loops or by parenteral penicillin therapy, all dogs lived over nine days, and 60 per cent survived more than thirty days. In the dogs that died there were observed ulceration, necrosis and infection of the gut wall most marked along the antimesenteric border. It was the opinion of these authors that, by controlling the bacterial growth by penicillin, ulceration and other effects of distention per se in a closed loop were not necessarily fatal.

Harper and Lemmer²⁰ found no damage to the intestinal wall in upper jejunal obstruction, but observed over 70 per cent intestinal wall damage in lower obstruction. They also noted that the lower the obstruction, with greater potential for distention, the greater the incidence and area of hemorrhage, necrosis and ulceration. Penicillin administered in large doses appeared to prevent these changes from occurring. This suggests that distention may prepare the way for bacteria to invade the gut wall, but that bacterial growth may be responsible for the ulceration and necrosis.

THERAPEUTIC CONSIDERATIONS OF DECOMPRESSION

In the past fifteen years, since the introduction by Wangensteen of means for control of intestinal distention by constant suction on an indwelling intestinal tube, and his definition of the mechanical derangements brought on by continued intestinal distention, there has been for the first time a general decline of the overall mortality of intestinal obstruction in this country. As a result of Wangensteen's work, and subsequent contributions by Abbott and Johnston¹ and others, nonoperative means are at hand by which control of distention can be effected. This, together with a more general appreciation of the mechanical aspects of obstruction and distention and their train of ill effects on the organism, has led to sounder and more rational approach to therapy.

Control of distention by constant suction intestinal intubation, in the absence of strangulation, often will, by itself, effect release of the obstructing mechanism. Experience has shown that best results have been attained in the obstructions due to adhesions, and in the postoperative ileus resulting from a combination of circumstances including postoperative inhibition, trauma, fibrinous adhesions, kinking and sepsis. Should intestinal intubation prove ineffectual and require operative intercession, or should surgical intervention be elected as initial primary therapy, suction provides a valuable adjunct by partially reducing the distention preoperatively and by preventing additional distention from forming postoperatively.

STRANGULATION OBSTRUCTION

Compromise of the intestinal blood supply producing strangulation of the bowel constitutes the most serious, dangerous and treacherous complication attending intestinal obstruction, and is the one complication that demands immediate operative intervention. Amongst those who utilize nonoperative decompressive therapy in the management of intestinal obstruction, accurate and prompt recognition of strangulation obstruction is imperative. It is around this ability or inability to recognize clinically strangulating or potential strangulating obstructions that disagreement arises as to the propriety of employing nonoperative decompressive therapy alone in the management of bowel obstructions. Strangulation may develop with considerable rapidity in association with certain types of adhesive bands, vascular accidents, intussusception or hernia; less rapidly with other types of obstruction. The degree of distention in association with strangulation may be such that other organs can be tolerated without major damage. The barrier of a healthy, viable peritoneum may prevent the spread of infection. If the bacteria invade the intestinal wall, sepsis may develop. The bacteria may invade the peritoneal cavity. Later frank necrosis and perforation of the intestine develop, with gross peritoneal contamination.

It is felt by most authors, and seems to be true clinically in the vast

majority of cases, that a strangulated segment of gut will not transport

nism per se, be it an adhesive band or a hernial ring, occludes the intestinal lumen as well as the blood vessels.

Recognition of Viability.—Absolute clinical recognition of viability in borderline cases of strangulation is a difficult task for even the most experienced surgeon. With the release of the obstructing mechanism a prompt change in color from the dark purple of strangulation to a healthy pink is fairly reliable sign of viability. However, the converse, although suggestive of nonviability, is not absolute, for on occasion dusky segments of bowel will survive. The return of good pulsations through an area of involvement indicates viability unless irreversible damage to the intestinal wall has taken place during the period of occlusion. Occasionally in the absence of strong pulsations, a tiny artery in the involved area can be sectioned and its bleeding observed. Transmission of peristalsis, although commonly mentioned as a criterion of viability, is relatively unreliable. With anoxia, active muscular contractions ensue which are difficult to differentiate from peristalsis. The use of fluorescein given intravenously and then observed under ultraviolet light gives an indication of blood flow through the intestine. Laufman and Method²² described a bowel surface temperature response as being an accurate index of viability. With strangulation, the temperature of the bowel surface fell below that of normal gut. When the strangulation was released before viability was compromised, the temperature returned to or above that of normal bowel. If after release the temperature stayed at its strangulation level, viability was always lost. They also observed that papaverine given intravenously was of considerable value in releasing residual vasospasm, thus aiding in the recovery of bowel following strangulation, provided the loop was recoverable.

Venous Obstruction. Due to their thin walls and relatively low internal pressure, interference with venous blood flow is the initial manifestation in most types of strangulations. Pure arterial obstruction is rarely encountered except in instances of accidental severance of the artery, arterial embolism or thrombosis. On the other hand, usual types of obstruction, encirclement, torsion, distention and intussusception cause for the most part venous occlusion or a varying combination of venous and arterial obstruction. With venous stasis the color of the bowel rapidly assumes a dark purplish blue and is early associated with marked venous engorgement and edema of the gut. As a result of increased venous pressure and stasis changes in capillary permeability occur, followed by extravasation of bloody fluid into the gut wall, intestinal lumen and free peritoneal cavity. Clinically the passage of bloody material by rectum or by vomiting under these circumstances should suggest strangulation of some type, and the finding in the course of an exploratory laparotomy of

bloody peritoneal fluid should immediately alert the operator to the possibility of some type of strangulating mechanism.

Blood Loss as a Cause of Shock in Intestinal Strangulation.—The factor of blood loss as a cause of shock in intestinal strangulations has been extensively studied by Scott and Wangenstein.³³ In venous obstruction alone there was observed an average increase in weight of strangulated loops of ileum of 283 per cent and an average blood volume decrease of 55 per cent. It was the feeling of these investigators that loss of blood locally into the gut wall, the intestinal lumen and the peritoneal cavity was of sufficient magnitude in itself to bring on the picture of shock. This effect is not so marked with arterial occlusion alone or when both arterial and venous occlusion occur at the same time. Under these circumstances the local loss of blood is not so great, and the animals survive a longer time, to die eventually of the effects of necrosis and perforation of the gut. The animals with venous obstructions, on the other hand, died early, usually in six hours from shock as a result of local blood loss.

Similar observations have been noted by Kremen and Nelson²¹ in studying the effects of ligation of the main superior mesenteric arteries and veins. In these experiments, dogs regularly succumbed early to venous occlusion of three hours' duration, usually with the picture of shock. Arterial occlusion could be tolerated up to four hours and if death occurred it was considerably later than in the venous group. Occlusion of both the arteries and veins caused the type of response observed with the arterial occlusion.

Absorption of Toxic Material from Strangulated Intestines.—Scott³² could find little evidence for direct absorption of toxic material from strangulated loops of intestine. He also injected intravenously into normal animals the peritoneal fluid of dogs having strangulated small intestine and could find no evidence suggesting the presence of toxic material in the peritoneal fluid until late in the course of the obstruction when the bowel was no longer viable and perforation had occurred.

Thrombosis.—With the slowing of circulation through the intestinal vascular bed and the clumping of cells that accompanies strangulation, conditions favorable for intravascular thrombosis undoubtedly exist. Laufman (1942)²⁵ felt that although heparin was effective in preventing thrombus formation and propagation, its use in strangulation was dangerous because it caused increased hemorrhage into the lumen and into the intramural tissues. On the other hand, Laufman felt it might be very helpful in preventing propagation of thrombi following resection of the strangulated segment of bowel.

Relationship of Bacteria to Viability.—Recent reports by Sarnoff and Poth,³¹ and Sarnoff and Fine³⁰ imply that in addition to the vascular effects per se, the bacteria present in the intestine may be a determining factor in survival from the effects of strangulation. These authors observed that although the ligation of all the venous return from a 50 cm. segment of ileum was regularly fatal to dogs, if the animals were

treated for ten days preoperatively with succinyl sulfathiazole orally, 70 per cent of treated animals survived indefinitely. By preventing bacterial proliferation it was possible for collateral venous return to develop through the omentum, mesentery, and to adherent loops. After thirty days the bowel appeared essentially normal, but prior to this they observed an extensive hemorrhagic infiltrate in the bowel wall with some early ulceration of the mucosa. The submucosa was hemorrhagic but intact.

Blain, Kennedy and associates (1946)⁸ obstructed the terminal ileum of dogs and then devascularized the terminal 60 cm of the obstructed segment. Such a maneuver was fatal to the control animals in twenty-six to thirty-six hours. In animals treated with penicillin, 100,000 units every two hours, all survived seventy-two hours, at which time it was possible to resect the devascularized segment with survival of four out of five animals.

Davis, Gaster and associates¹⁰ studied the degree that bacteria contribute to the damage to the intestine of rabbits, resulting from inadequate blood supply. They found that streptomycin, 200 mg. daily given subcutaneously to a 2 kg. rabbit, prevented death in each of twelve animals after devascularizing a 7.5 cm. segment of ileum, a procedure that caused 80 per cent deaths in a control group of animals. In the surviving animals the 7.5 cm segment was found to have contracted to 5 to 6 cm. It was adherent to the omentum, parietal peritoneum and adjacent loops of intestine, from all of which it seemed to be deriving some blood supply.

These studies suggest that the lethal effects of strangulation relate to local blood loss with shock, and as a result of the intestinal infarction there is an invasion of the intestinal wall by bacteria, leading to early necrosis, dissolution of continuity and perforation. These effects of bacterial proliferation can be delayed by antibacterial agents such as succinylsulfathiazole, penicillin, and streptomycin, and if the segment of bowel involved is not too extensive, they may delay a fatal outcome long enough for adequate collateral vascular channels to develop. It is of clinical significance that these agents will prolong survival time in experimental intestinal strangulation, and their use is certainly indicated in all cases of acute intestinal obstruction, particularly where the possibilities of strangulation may exist. However, under such circumstances they should be employed as an adjunct to and not as a substitute for early operation.

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SURGICAL PHYSIOLOGY OF PANCREATITIS

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The past decade has brought considerable progress in the understanding of acute pancreatitis. The advances have been chiefly an understanding of the response of the pancreas to injury and of the effect of this injury on the body rather than in demonstrating the basic cause of the disease.

ETIOLOGY

No etiological agent common to every patient with acute pancreatitis has as yet been demonstrated. An infectious origin seems unlikely. No epidemic has ever been reported. Certain features of the disease, such as the associated frequency of jaundice and other signs of hepatic impairment, have led investigators to inquire whether acute pancreatitis, and the edematous form in particular, might not represent an associated or "aberrant" infection of the pancreas by the virus of infectious hepatitis.¹ The question cannot yet be settled, but certain interesting observations have been made.

Pancreatitis is unusual as a finding associated with epidemics of hepatitis but does very rarely occur. Conversely, biopsy of the pancreas and liver of eight patients with typical acute edematous pancreatitis revealed marked inflammatory changes in the pancreas but only slight changes in the liver.² Certainly these patients did not present typical histological evidence of hepatitis. Furthermore, efforts by one investigator to transmit the acute pancreatic disease to himself have been unsuccessful.² The latter experiment consisted of attempts to transmit the disease from three patients during the first week of their illness with the edematous form of the disease as proved by laparotomy. In each instance blood serum was transmitted intravenously promptly after withdrawal from the patient. In addition, saliva, gallbladder bile, urine, feces, blood, and in one instance pancreatic juice, were taken orally, intranasally, and by ingestion in acid-resistant capsules intended to release the material within the intestine. Serum amylase concentrations, liver function studies, and symptomatology, over a period of six to eighteen months, have not suggested pancreatic or hepatic disease. Such an experiment on a single subject is, of course, inconclusive but has not suggested any form of infectious origin of the usual "idiopathic" pancreatitis. The virus of mumps occasionally produces an acute pancreatitis either as a complication or

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independent of a parotitis. Epidemiologically, this virus is hardly the cause of the acute pancreatitis commonly seen. Twelve patients with acute edematous pancreatitis have had skin tests, and several have had complement fixation tests, for mumps during the ensuing six months. In no instance was there evidence by such tests of infection by mumps virus.²

Most investigators have believed that the regurgitation of bile from the common bile duct into the major pancreatic duct is the chief etiological factor. Certainly, in the experimental animal the injection of bile or of bile salts into the pancreatic duct results in a diffuse inflammation of the pancreatic parenchyma not unlike that seen clinically. Furthermore, study of fresh autopsy specimens reveals that such a regurgitation is anatomically possible in a majority of people.³ Investigators who have postulated this etiology have held to the theory that bile salts, in the alkaline pancreatic medium, were necrotizing and that calcium, or some property of the bile, activated the pancreatic trypsinogen to the proteolytic enzyme, trypsin. The bile salts and the trypsin have therefore been held responsible for the death and partial hydrolysis of the pancreatic cells.

Two criticisms of this theory are evident. First, autopsies of patients with acute pancreatitis sometimes show such regurgitation or "common channel" etiology anatomically impossible in the individual patient. Secondly, many patients have the "common channel" or anatomical prerequisite, but never develop pancreatic inflammation. Radiologists, not infrequently, have shown during cholangiography that dye regurgitated from the common bile duct into the pancreatic duct (Fig. 609) but most of these patients give no history suggestive of pancreatitis. However, the theory of the reflux of bile is rather widely held and is to a large extent the basis of the decompression of the extrahepatic biliary tract in the management of these patients.

Other investigators have postulated that the cause of pancreatitis is the obstruction of the pancreatic ducts of a healthy, secreting gland.⁴ They have pointed out that pancreatic or common duct calculi, metaplasia of the pancreatic ducts, or edema of the duodenal mucosa from alcohol or other irritants might cause obstruction. In criticism of such a concept, it should be recalled that the main pancreatic duct frequently communicates with the accessory pancreatic duct of Santorini which empties into the duodenum several centimeters from the ampulla of Vater. In these patients, obstruction at the ampulla of Vater by a common duct stone or spasm of the sphincter of Oddi could hardly cause obstruction to the outflow of pancreatic juice. Moreover, surgical ligation of the pancreatic ducts following partial pancreatectomy in patients and simple ligation in experimental animals has led only to a very mild pancreatitis, not to the hemorrhage and necrosis which are encountered in clinical practice. Yet even if the regurgitation of bile into the pancreatic ducts is the etiological explanation for the disease, the differen-

tial pressures permitting the reflux of bile must offer at least a partial obstruction to pancreatic outflow. This, at least, seems the case in cholangiography. McGowan measured the pressure in the common bile duct to be 50 mm. of water, whereas after morphine had produced spasm of the sphincter of Oddi, 500 mm. of water pressure permitted a slight regurgitation of radiopaque fluid from the common duct into the pan-

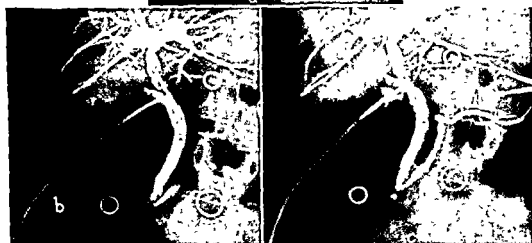


Fig. 600. Cholangiograms. (a) Normal. (b) and (c) after morphine.

creatic duct.⁵ The secretory pressure of the human pancreas has not been accurately measured while that of the liver is about 220 mm. of bile (325 mm. water).⁶ The role of the gallbladder in regulating the maximal pressure in the common duct seems unimportant as its intraluminal pressure never exceeds the secretory pressure of the liver. Of clinical interest is the fact that pancreatitis occurs occasionally in patients whose gallbladder has been removed, again suggesting that the gallbladder is unnecessary in forcing bile up the pancreatic duct.

THE RESPONSE OF THE PANCREAS TO TRAUMA

Basically, the response of the pancreas to injury is similar to the response of other abdominal organs. The irritation produces a reactive inflammation which presents a rather constant pattern on histologic study. Edema and vascular engorgement are accompanied by a polymorphonuclear and lymphocytic exudation. As the local edema and exudate increase, there is distention of the pseudocapsule of the pancreas and irritation of the posterior peritoneal wall. Pain results and is localized chiefly to the back and epigastrium. Distention of the pancreatic ducts occur with radiation of the pain to the left side. Further distention of the biliary tree may produce right upper quadrant radiation of the pain.¹ Pancreatic pain is conveyed by the splanchnic nerves. It is probable that inflammation limited to the uncinate process of the pancreas may cause radiation of pain to the right lower quadrant, but in general radiation of pain from the head of the pancreas is experimentally identical with that from the common duct, cystic duct or cystic artery.

Edema, vascular engorgement, and exudate produce swelling of the pancreas, most commonly found in the pancreatic head. Obstruction of the pancreatic ducts, if not an etiological factor, might result. This is the characteristic finding in edematous pancreatitis and pathologically seems similar to the early picture of acute appendicitis or acute cholecystitis. Like edema in these other processes, edema of the pancreas may produce pressure and secondary ischemia. Pressure may be exerted directly on the branches of the pancreatoduodenal arteries and the associated veins. In addition, the proximity of the disease to the celiac and other sympathetic ganglia may result in vascular spasm. Thus ischemia will promote pancreatic necrosis which in turn will lead to additional edema and exudate, additional pressure and additional ischemia. With progression, as in the ischemia and necrosis of strangulating bowel, the exudate may change from a clear to blood-tinged appearance. At times, areas of necrotic pancreas may seem almost caseous in gross appearance. Finally there may be necrosis of the vascular walls with frank hemorrhage.

This relationship between pancreatic edema and pancreatic necrosis is not proved but such a pathogenesis for the various forms of acute appendicitis, acute cholecystitis and acute diverticulitis has been demonstrated. Furthermore, this relationship between pancreatic edema, necrosis and hemorrhage has been supported by the experimental observations of Popper, Necheles and Russell.² They demonstrated that ligation of the pancreatic ducts and intravenous injection of secretin in the dog produced edematous pancreatitis. If, at the same time, the arterial blood supply was temporarily occluded, necrotizing and hemorrhagic pancreatitis occurred instead of the edematous form. This theory of relationship between the two processes has been criticized on the basis of the experimental work of Popper and Necheles.³

As the pancreas develops, edema extends around the

common duct, retroperitoneally beneath the pouch of Morrison, and occasionally over the right lobe of the liver. Similarly, it may extend laterally around the kidneys or rarely anteriorly along the round ligament to the umbilicus. Advanced inflammation and necrosis may be associated with a retroperitoneal spread of edema and necrosis down along the aorta and iliac vessels to the pelvis.

Owing possibly to the distention of the pancreatic ducts with resultant rupture of the ductules or acini or because of increased permeability of the acinar cells from ischemia, there is a release of the pancreatic enzymes into the peripancreatic tissues and into the peritoneal cavity. The peritoneal fluid, ranging up to several hundred cubic centimeters in quantity, is an exudate with a very high concentration of protein including fibrin. It may be clear or contain hemolyzed or nonhemolyzed red cells. In addition, the three pancreatic enzymes are present in high concentration (Table 1). Thus there may be an enzymatic peritonitis, for some of the

TABLE 1
PANCREATIC ENZYMES IN PERITONEAL FLUID IN ACUTE PANCREATITIS

Patient	Amylase (Somogyi)	Lipase (cc N/10 NaOH)	Trypsin
S.T.	> 300	Present	Present
D.D.	> 300	0.4	8.3
M.H.	> 3500	24.4	7.4
M.B.	2380	26.3	6.0
S.O.	1800	18.1	5.9
R.N.	2216	21.9	11.0
G.S.	8000	Present	Present
V.S.	4800	31.1	9.4

features of the peritoneal inflammation may be due to the presence of the enzymes in the peritoneal cavity, although Dragstedt, Haymond and Ellis have demonstrated that in the absence of infection the enzymes produce only a mild peritoneal reaction. As the pancreatic inflammation produces necrosis of the gland and of the surrounding tissues, the enzymes are present in the peripancreatic and peritoneal fluid to speed the hydrolysis of the necrotic tissue. The current concept of enzymes is that they are catalysts and can only speed chemical reactions but not initiate them. Thus lipase cannot hydrolyze living fat cells but can speed the hydrolysis of necrotic fat to fatty acids and glycerine. Ionized calcium can then combine with the fatty acids to form soaps, the white plaques of "fat necrosis." Thus most of the necrotic fat and the greater concentration of lipase are near the pancreas and adjacent viscera so it would be expected that most of the "fat necrosis" would be found in these areas. However, as the inflammation and necrosis may spread from the pancreas to distant areas, and since the enzymes are present in the peritoneal exudate, "fat necrosis" may occasionally be found scattered throughout the peritoneal or retroperitoneal tissues.

These calcified plaques may be found during the first twenty-four hours of the illness. After two weeks they may be encapsulated with fibrous tissue and grossly may not be recognizable.² Their ultimate fate has not been demonstrated.

Since edematous pancreatitis may be found without evidence of "fat necrosis", one might infer that the inflammation in such patients was not severe enough to produce tissue destruction, a prerequisite for the action of lipase.

The amylase is also released locally into the tissues and peritoneal fluid (Table 1). Possibly it too reacts locally to speed the hydrolysis of glycogen in the tissues. No experimental data is available, however, to verify this.

Studies of the peritoneal exudate (Table 1) reveals that activated trypsin is present. Its local action in producing hydrolysis of protein has been the basis of the "trypsin theory" of the etiology of pancreatitis. Its presence in the peritoneal exudate does not, however, prevent the formation of a fibrin clot in this exudate.

THE REACTION OF THE BODY TO PANCREATIC TRAUMA

Increased Concentration of Circulating Enzymes.—The damage to the pancreatic acini and the release of enzymes into the surrounding tissues results in an absorption of these enzymes into the blood stream. In the experimental animal, this absorption, at least of amylase, is partially by way of the lymphatics¹⁰ but is chiefly a direct absorption into the blood stream as the blood courses through the damaged pancreas. Note that, following the production of experimental pancreatitis by the ligation and subsequent injection of bile into the pancreatic ducts of the dog, the amylase concentration is higher in the serum from the pancreatic vein than in the serum from the pancreatic artery (aorta)¹¹ (Fig. 610). This demonstrates that the enzyme is absorbed directly into the blood stream and that the damaged pancreas is the source of the increment. This experiment further demonstrates the dilution effect in the portal vein and again in the peripheral blood stream. Thus the high amylase concentration in the peripheral blood stream may be associated with a much higher concentration in the pancreatoportal circulation.

Normally the concentration of amylase of the peripheral blood is 80 to 160 Somogyi units per 100 cc. of serum (and 20 to 35 Somogyi

This concentration of amylase in the serum is rather constant but it may increase to diagnostic levels within a few hours after pancreatic trauma; diagnostic levels being considered any concentration over 300 Somogyi units per 100 cc. of serum.

As the concentration of amylase increases in the serum, the amount excreted in the urine increases, a fact which was utilized in the earlier

diagnostic tests. This increased serum amylase concentration and excretion seemingly is maintained so long as there is progressive pancreatic damage, usually falling to a normal level after forty-eight to ninety-six hours. After extensive pancreatic necrosis, amylase may almost disappear from the serum.

Similarly, serum lipase concentration is increased and the elevation may be prolonged for several days after the amylase concentration has fallen to normal, a fact which may be of occasional help in the late diagnosis of pancreatitis. Until recently, the determination of lipase con-

Concentration of Amylase in Serum of Pancreatic Artery (aorta), Pancreatic & Portal Veins after Production of Experimental Pancreatitis

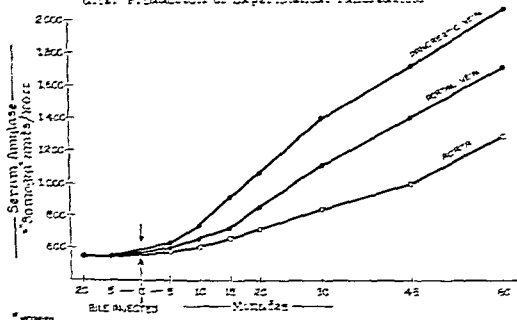


Fig. 610.—Concentration of amylase in serum of pancreatic artery (aorta), pancreatic and portal veins after production of experimental pancreatitis (Courtesy Surgery.)

centration required twenty-four hours whereas, the determination of amylase concentration required only thirty minutes to two hours. The latter test has therefore been considered the preferable diagnostic test in the presence of acute abdominal disease. It is of practical, clinical interest that if serum is removed from the cells and refrigerated, the amylase concentration changes very little within twelve hours and the test remains clinically valid during this time.¹²

The concentration of trypsin in the serum cannot be accurately measured but probably, it, too, is elevated.¹

The systemic action of these circulating enzymes has not been demonstrated but in all likelihood they have some role in metabolism outside the bowel as their presence in the serum, at least of amylase, is a

characteristic of all mammalian life.¹³ Might they be hormones, toxic in high concentration, as are insulin, epinephrine and thyroxine, especially in the high concentration in which the pancreatic enzymes reach the liver

Hepatic Damage.—Borgström¹⁴ gave trypsin intravenously to rabbits and noted a lowering of prothrombin and fibrinogen levels. The fall in prothrombin level was confirmed in patients with pancreatitis but this is far from conclusive evidence of specific trypsin action, for liver damage is frequently associated with pancreatitis. Many of the patients are jaundiced. Cephalin flocculation, colloidal red, thymol turbidity and thymol flocculation tests very frequently reveal evidence of hepatic damage and this damage may parallel in degree the pancreatic damage.² The cause of the hepatic damage is not clear. It may be due to common bile duct obstruction but the stools are seldom acholic and the jaundice may deepen in the presence of a functioning cholecystostomy. It may be due to a bacterial or enzymatic cholangitis as either may sometimes be demonstrated. Again the hepatic damage may be due to some unidentified toxin from the traumatized pancreas. Liver biopsies reveal minimal periportal inflammatory and degenerative changes.² In experimental bile pancreatitis, Ireneus¹⁵ demonstrated definite histologic evidence of hepatic damage consisting of generalized edema, cloudy swelling of the cells around the central vein and periportal areas, and parenchymal necrosis. In some animals fatty degeneration, hemorrhage, and extensive necrosis of the hepatic cells were noted.

Impairment of Gallbladder Function.—There is frequently a coincident abnormality of gallbladder function. Many surgeons have noted the high incidence of gallbladder disease associated with pancreatitis, but Silvani and McCorkle¹⁶ have presented evidence of impairment of the function of the "normal" gallbladder during acute pancreatitis. These authors found that intravenous cholecystography revealed a failure of gallbladder visualization in sixteen of twenty-eight patients with acute pancreatitis. This phenomenon in the "normal" gallbladders studied persisted for approximately a week after which the gallbladder regained the function of dye concentration. The authors found no evidence that the failure of gallbladder visualization was due to failure of the liver to excrete the dye.

Other Gastrointestinal Effects.—The effect of the disease on the rest of the gastrointestinal tract seems nonspecific. Reflex nausea and vomiting are characteristic. The retroperitoneal inflammation and the enzymatic, chemical and bacterial peritonitis produce an ileus of varying intensity. Rarely is a patient with acute pancreatitis seen who does not initially have an absence or marked diminution of peristalsis. The ileus associated with severe pancreatic necrosis may persist for many days and the secondary distention may simulate that seen in obstruction of the left colon.

Intubation of the duodenum during the first few days of the illness may show a temporary absence of pancreatic enzymes, due probably

to obstruction of the pancreatic ducts.² Absence of bile, however, is unusual.

Cardiovascular-Hematologic Effects.—The disease is reflected on the cardiovascular-hematologic system by hemoconcentration and decreased blood volume. Varying degrees of peripheral vascular shock may occur as with any other form of peritonitis or intra-abdominal necrosis. Tachycardia and occasional rise in the blood pressure occur. This hypertension and injury to the myocardium as reflected by electrocardiograms have been attributed to the action of trypsin,¹ but it is quite likely that these changes are nonspecific.

Leukocytosis, of course, occurs as the white blood cells are mobilized as a result of necrosis and infection. Hypocalcemia has been reported¹⁷ and attributed to the removal of the circulating calcium ions to form the soaps of "fat necrosis," but calcium excretion studies have not been reported. Tetany must be a rare sequela if, indeed, it ever results.

Hyperglycemia is a common finding during the acute illness. This has been attributed to the destruction of the islet cells by the inflammatory process. However, since the islet tissue contains insulin, one might expect a release of insulin, as with amylase and lipase, resulting in a transient hyperinsulinism and hypoglycemia. Such a hypoglycemia has not been noted. The release of epinephrine by sympathetic stimulation may be partially responsible for the elevated sugar concentration. Again, the systemic action of amylase has not been demonstrated and in high concentration it conceivably might cause the hydrolysis of stored carbohydrates and the release of glucose to the blood stream.

Respiratory Tract.—The manifestations of the disease on the respiratory tract seem only to be the high incidence of pulmonary atelectasis secondary to the paralytic ileus and abdominal distention. In addition, pleural effusion may result from the subdiaphragmatic inflammation.

Impaired Wound Healing.—Wound healing is frequently slow in these patients. This is in part due to ischemia as the patients are usually obese and distended. A transient diabetes may affect wound healing and encourage wound infection. *Nutrition cannot be maintained in the patients with progressive necrosis. As a result, the incidence of wound disruption is higher than in most abdominal diseases.*

Infection.—The cause of death from pancreatitis is toxemia, and the cause of the toxemia seems to be infection. Infection may not be a primary factor in the etiology of pancreatitis but, if not, secondary invasion of the inflamed pancreas, the bile and the peritoneal exudate is frequent. Cultures taken from the pancreas which is mildly inflamed are frequently sterile but, as the inflammation progresses, invasion by pathogens is favored by the presence of ischemia and necrotic tissue. Experimentally, sterile pancreatic juice in the peritoneal cavity does not produce a profound toxemia, but infected pancreatic juice produces a widespread necrosis, toxemia, and death of the animal.⁹

Cultures of the bile and pancreas from the last fifty patients with acute pancreatitis studied at the Hospital of the University of Pennsylvania

were positive in thirty-five instances (70 per cent) at the time of operation. The cultures were positive in almost every instance where late operation was necessary because of necrosis. Occasionally the organisms were of doubtful pathogenicity but the presence of virulent gram-positive and gram-negative organisms can be anticipated in a high incidence of patients.

TRAUMATIC PANCREATITIS

Because of its position in the retroperitoneal space, overlying the vertebrae, the pancreas is seldom injured by external force. Traumatic pancreatitis results nearly always from a direct injury, that is, a stab wound or other penetrating injury. Infrequently, injury of the pancreas may occur by indirect transmission of force from a blow on the anterior abdominal wall. This represents injury to a healthy, functioning gland. Necrotic tissue is usually minimal and neither bile salts nor activated trypsin is present in the pancreas. In the absence of associated injuries, the manifestations are usually those of a slowly developing retroperitoneal collection. A period of latency of several days may exist but, as the secreting gland continues to function or develops a temporary secretory inhibition and recovers, pancreatic fluid accumulates, usually outside of the capsule. As the fluid follows cleavage planes, it may present laterally or retroperitoneally over the sacral prominence. Very high concentrations of the pancreatic enzymes may be found in the serum in these patients. Shallow and Wagner reported a serum amylase concentration of 6400 units in a boy who had experienced a nonpenetrating abdominal injury.¹³ The patient, aged 8 years, withstood the injury almost on an ambulatory basis. Again it should be emphasized that traumatic pancreatitis differs from the more common type by the absence of necrotizing agents, by the presence of a healthy biliary tract, and possibly by the absence of pancreatic ischemia.

HEALING OF PANCREATITIS

The pancreas heals by fibrosis and probably by regeneration.

The current theories of pathogenesis do not fully explain why the inflammation is reversible unless the obstruction at the sphincter of Oddi or of the pancreatic ducts is released, or a secretory inhibition of the pancreas might contribute to the recovery by lessening intraglandular pressure.

In experimental bile pancreatitis,¹⁵ edema and other inflammatory changes begin subsiding during the first week. By the end of the first week, fibroblastic tissue has proliferated to fill the interlobular spaces and distort the acini and lobules. Meanwhile, the acinar cells which retain their basement membranes intact recover and presumably retain their ability to function. At the same time, the necrotic cells undergo autolysis and seem to be, in part, replaced by ductal proliferation.^{16,20}

In the mild, edematous pancreatitis (experimental), histologic recovery is almost complete in ten to fourteen days and the pancreas cannot be differentiated from a normal gland. If the pancreatitis is more severe with patchy necrosis and hemorrhage, histologic recovery is complete in one month but residual fibrosis and distortion of the acini remain.¹⁵

Clinically, the exudate gradually absorbs but the edema may persist for several months after symptomatic recovery. The areas of "fat necrosis" become encapsulated and may not be recognizable one month after the initial attack.

Functional recovery, as manifested by the secretion of enzymes into the duodenum, usually takes place within the first week unless the necrosis of the pancreas is progressive. With repeated episodes of pancreatitis, this secretion may gradually decrease as the acinar tissue is destroyed and finally with fibrotic obstruction of the ducts, may disappear. Histologically, such a pancreas reveals marked cirrhosis with relative preservation of the islet tissue.

Massive necrosis and hemorrhage may heal by fibrous encapsulation giving rise to the pseudocyst. Such a cyst, like the subdural hematoma, may still contain blood several months later. The designation of "encapsulated hematoma" changes to "pseudocyst" as the old blood is absorbed. Some of the fibrous lined cysts contain pancreatic enzymes even though sometimes no communication with the pancreatic ducts can be demonstrated.

THE PHYSIOLOGICAL ASPECT OF TREATMENT

The measurement of the serum amylase concentration as a short, diagnostic test of acute pancreatitis permits the clinician to outline a definitive course of therapy.

Application of the physiological principles to treatment of acute pancreatitis has centered around:

1. Decompression of the biliary tract and prevention of reflux of bile into the pancreatic ducts.
 2. Prevention of ischemia to the pancreas.
 3. Treatment of the associated peritonitis and its sequelae.
 4. Drainage of pancreatic collections.
- Intubation of the biliary tract permits its decompression and so tends to prevent reflux of bile into the pancreatic ducts. This has the practical advantages also of permitting drainage of infected bile, diagnosis and treatment of acute biliary tract complications and may be combined with drainage of pancreatic collections. It also permits cholangiography at a later date. Morphine produces spasm of the sphincter of Oddi and so should be avoided. Conversely, atropine may be used in an effort to decompress the common duct by relaxing the sphincter—an action which has not been conclusively demonstrated. Doubilet and Mulholland have suggested division of the sphincter of Oddi to prevent recurrences.¹

Efforts to prevent pancreatic ischemia have centered around splanchnic nerve and celiac ganglion procaine blocks, drainage of the pancreas to lessen intracapsular tension, maintenance of normal blood volume and hemoglobin content, and maintenance of pulmonary aeration by prevention of pulmonary complications.

Similarly in an effort to stop secretion of the acini, the indirect stimulus of food in the stomach should be avoided, and some investigators^{21,22} have suggested irradiation of the pancreas to depress secretion.

The treatment of the peritoneal irritation and infection has consisted of maintenance of blood volume, chemotherapy and antibiotics, and decompression of the gastrointestinal tract.

The application of these principles has resulted in a marked decrease in mortality from this disease, the greatest decrease in mortality having followed the introduction of antibiotics.

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CLINICAL EXPERIENCES WITH SURGICAL LESIONS OF THE PANCREAS

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The pancreas, because of its position, its blood supply and its essential role in metabolism, was long known as the hermit organ of the abdomen and for many years surgeons seldom attempted any operations upon it. With the development of modern adjuvants to pancreatic surgery in the last ten years and largely due to the pioneering efforts of Whipple, Brunschwig, and others, operations are now being done for acute pancreatitis in its various forms, for chronic pancreatitis, for chronic relapsing pancreatitis, for pancreatic calculi, for cysts of the pancreas, for pancreatic carcinomas, and for adenomas or hyperplasia of the islet cells.

The purpose of this paper is to discuss the pros and cons of some of these operations and to make an attempt to evaluate some of them from the standpoint of operative mortality and prognosis. It must be said at the outset that any such evaluation must be tentative, and in some cases purely preliminary, because the experience acquired so far is limited and much is yet to be learned about the physiological problems involved in pancreatic surgery.

Our experience at the Hospital of the University of Pennsylvania has been reviewed for the period 1932 to 1949 in an attempted survey of this field. Table 1 shows the distribution of these cases in the various categories.

ACUTE PANCREATITIS

Acute pancreatitis comprises acute edematous (interstitial) pancreatitis, with or without fat necrosis; acute hemorrhagic pancreatitis and acute necrotizing pancreatitis. Most authors use the last two terms synonymously, but the differentiation between the cases with edema and fat

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necrosis and those with hemorrhagic and necrotizing pancreatitis is not always clear.

TABLE 1
SURGICAL LESIONS OF THE PANCREAS
Hospital of the University of Pennsylvania, 1932-1949

Diagnosis	No of Cases	Incidence in Entire Series
Carcinoma of the pancreas	55	37.6
Acute edematous pancreatitis	38*	26.0
Acute necrotizing or acute hemorrhagic pancreatitis	16	11.0
Abscess of the pancreas	1	.7
Chronic pancreatitis	11	7.5
Pancreatic cysts and pseudocysts	8	5.1
Cystadenoma	1	.7
Pancreatic calculi	4	2.7
Chronic relapsing pancreatitis	4	2.7
Tumors of the islands of Langerhans	6	4.0
Ectopic pancreatic tissue	3	2.0
Total	147	100.0

* Five treated without operation

TABLE 2
ACUTE PANCREATITIS
Hospital of the University of Pennsylvania, 1932-1949

	Necrotizing and Hemorrhagic	Edematous
Total number of cases	16	38
Temperature (on admission)		
Minimum	99.0	97.4
Maximum	102.0	101.2
Average	99.6	99.9
White blood count (on admission)		
Minimum	10,000	6,700
Maximum	33,500	34,800
Average	16,796	16,335
Pulse (on admission)		
Minimum	68	54
Maximum	116	128
Average	89.5	92.0
Respiration (on admission)		
Minimum	18	20
Maximum	32	38
Average	24.7	24.4

There are those who take the point of view that hemorrhagic pancreatitis is a separate clinical entity because the mortality is higher. This we find difficult to believe. Almost any serious disease could be divided between the milder and the more severe cases on the basis of one criterion or another. The situation is further complicated by the teaching in the

older textbooks that operation should not be done in acute pancreatitis. Thus, in many patients presumed to have had pancreatitis, a definite diagnosis was never established unless it was eventually confirmed at autopsy. In recent years, the serum amylase has proved useful in making the diagnosis of acute pancreatitis preoperatively, but it is unlikely that it can be relied upon to distinguish between the edematous and the hemorrhagic forms of the disease.

As Table 2 indicates, the leukocyte count, the temperature elevation, and the pulse and respiratory rates were of no value in making such a differentiation. The age range and sex distribution are likewise of no real assistance (Table 3).

TABLE 3
SURGICAL LESIONS OF THE PANCREAS
Hospital of the University of Pennsylvania, 1932-1949

	Per Cent Male	Per Cent Female	Young- est	Oldest	Average Age
Carcinoma . .	55.6	44.4	35	78	57.6
Edematous pancreatitis	20.0	80.0	19	72	42.8
Necrotizing pancreatitis	30.8	69.2	33	85	52.5
Chronic pancreatitis	50.0	50.0	38	63	53.8
Pancreatic cysts . . .	50.0	50.0	6	53	35.1

As a working hypothesis, it seems wise to regard all acute pancreatitis as potentially dangerous. For example, in two cases in our files, the patients showed relatively mild symptoms with tenderness most prominent in the right lower quadrant. Both had appendectomies and the diagnosis of acute pancreatitis was not made at operation. Both became gradually sicker and died three to four days postoperatively and at autopsy had hemorrhagic necrotizing pancreatitis. Certainly, they did not present the dramatic picture of hemorrhagic pancreatitis at the time of admission and it seems possible that they began with edematous pancreatitis, which progressed to the more severe form of the disease.

Another point in favor of regarding edematous and necrotizing pancreatitis as two forms of the same disease, is that there have been six patients who recovered from edematous pancreatitis at this hospital who developed subsequent attacks of pancreatitis. Two of these had hemorrhagic pancreatitis and died.

It is not easy to interpret the mortality figures for acute hemorrhagic pancreatitis from the literature. In the fulminating forms of the disease, diagnosis is often so uncertain that operation is done even by those surgeons who believe in nonoperative management of pancreatitis. Operative results in themselves are controversial. Paxton and Payne¹ in a recent statistical review of a large series of cases of acute pancreatitis, found that there was an over-all mortality of 33.3 per cent.

Among the patients who were operated upon as emergencies, the mortality was 44.7 per cent, while in the group who were not operated upon the mortality was 21.3 per cent. Thus, the authors felt, was equally true for either the acute edematous or hemorrhagic variety. However, if operation is not done, no one can ever be entirely certain whether or not the patient had hemorrhagic pancreatitis, unless the patient dies and autopsy is performed.

Since penicillin has become available, the mortality of acute pancreatitis has been markedly reduced. In our series, there was a reduction from 18 per cent to 3.2 per cent. Analysis of the figures reveals that the edematous form dropped from 9.7 per cent to zero, while the hemorrhagic and necrotizing types of acute pancreatitis showed a reduction in mortality from 45 per cent to 20 per cent (Table 4). The single death encountered during the penicillin era (1945-1949) resulted from hemorrhage and necrosis of the entire pancreas.

TABLE 4
MORTALITY OF ACUTE PANCREATITIS
Hospital of the University of Pennsylvania, 1932-1949

	Edematous		Hemorrhagic and Necrotizing		Total	
	No. of Patients	Mortality	No. of Patients	Mortality	No. of Patients	Mortality
1932-1945	31	9.7%	11	45%	41	18 %
1945-1949	26*	0	5	20%	31	3.2%

* Includes 5 patients treated without operation

The usual operation is cholecystostomy and drainage of the pancreas. The latter is accomplished by incising the peritoneal attachments of the descending portion of the duodenum and placing drains against the head of the pancreas behind the duodenum and by opening the gastocolic omentum into the lesser peritoneal cavity for drainage of the body and tail of the organ.

The cholecystostomy is carried out because it is thought that many cases of pancreatitis are due to a reflux of bile into the pancreas, as a

from a number of studies. It was further confirmed at the University of Pennsylvania a few years ago in a careful study of autopsy material at the Philadelphia General Hospital.³ In a series of 150 individuals, a

choledocholithiasis and acute cholecystitis recorded in our series as well as the occurrence of hyperbilirubinemia is shown in Table 5.

The use of drains for the pancreas itself is based, partly on the need for an avenue of escape for necrotic pancreatic tissue and pus, and, partly to provide an exit for the pancreatic enzymes which appear to be released into the peritoneal cavity. It is well known that simple pancreatic fistulas, sometimes produced in operations for duodenal ulcer, are seldom fatal as long as drainage to the outside is established. The situation in acute pancreatitis is different in that the proteolytic enzymes appear to be activated. However, this would seem to be only an additional reason for providing drainage.

Further review of the experience at the Hospital of the University of Pennsylvania revealed additional cases from the autopsy files in which no purposive operation was done. We shall not attempt to specify the per cent mortality of nonoperative treatment because there is no way of knowing how many patients not operated upon actually had the disease. Suffice it to say, that of the twenty patients who died with this condition

TABLE 5
PANCREATITIS
Hospital of the University of Pennsylvania, 1932-1940

	Edematous	Hemorrhagic and Necrotizing
Number of patients studied	57	16
Serum bilirubin		
0 to 0.5 mg. per 100 cc.	11%	
0.5 to 2.0 mg. per 100 cc.	40%	
Over 2.0 mg. per 100 cc.	40%	100%
Acute cholecystitis.	21%	12%
Cholelithiasis.	41%	50%
Choledocholithiasis	5%	37%

since 1922, eleven or 55 per cent either had no operation or an irrelevant operation not directed against the pancreatic disease.

In summary, we have to date employed an operative treatment in the management of most patients with acute pancreatitis because of the following considerations:

1. Decompression of the biliary tract reduces the probability of reflux of bile into the pancreatic ducts.
2. Acute biliary tract complications are discovered and treated.
3. Enzyme tests do not differentiate between primary pancreatitis and pancreatitis secondary to inflammation in an adjacent organ—e.g., perforated posterior ulcer.
4. Operation permits the establishment of drainage tracts for necrotic or infected pancreatic tissue, fluid containing pancreatic enzymes and infected bile.
5. Operation provides a means of later examining the common bile duct roentgenologically. With the combined use of operative intervention and a peritonitis regime postoperatively, the mortality has declined to 3.2 per cent in the last thirty-one cases.

... elective surgery to the pancreas or the
 ... the residual
 inflammation is ... times still
 been quite marked three or four months ... recovery.
 ... routinely recommend cholecystectomy after emergency
 ... of acute calculous cholecystitis,
 ... after
 titis may later recur.

CHRONIC PANCREATITIS

Chronic inflammation of the pancreas may range from moderate fibrosis with vague digestive disturbances and epigastric pain to chronic enlargement of the pancreas with jaundice and cachexia which is difficult, if not impossible, to differentiate from malignancy. That pancreatitis can at times mimic carcinoma, even to the production of common duct obstruction, is attested by the occasional recovery and prolonged survival of patients with supposed carcinoma following cholecystojejunostomy. Under such circumstances, radical operation has been performed by experienced surgeons, without malignancy being found on pathological examination of the resected specimen.

CHRONIC RELAPSING PANCREATITIS

This disease entity represents the severe forms of chronic pancreatitis with exacerbations separated by long or short periods of remission. The damage to the pancreas probably can be demonstrated clinically. It may be revealed by decreased volume and concentration of pancreatic enzymes in aspirated duodenal juice, excess nitrogen and excess total and unsplitted fat in the feces, diabetes, calcification in the pancreas as demonstrated by x-ray, or, formation of pseudocysts.

Perhaps the symptomatology is best outlined by a patient whom we followed for several years. After a gallbladder operation performed elsewhere, he had persistent symptoms at the time of his first admission to the Hospital of the University of Pennsylvania. His common bile duct was explored but the only positive finding was a swollen hard pancreatic head. A biopsy showed fibrosis. In this instance there was a small collection of bloody fluid which we aspirated through a needle from the head of the gland.

The patient did well for several months but failed to gain weight. He then returned with nausea, vomiting, and epigastric pain. Gastrointestinal films and biliary drainage were negative. He was carried along symptomatically until it was postulated that his vomiting was due to interference with the mobility of his duodenum and a gastro-

enterostomy was performed. His vomiting subsided, but the bouts of epigastric pain persisted. Flat films of the abdomen revealed a hazy area in the region of the pancreas, interpreted as calcification in the parenchyma of the gland. As time went on, this became more dense, the attacks of pain continued at intervals, and the patient developed frank diabetes and required insulin. In such patients in whom the diagnosis of chronic pancreatitis and pancreatic calcification has been established and who fail to respond to conservative therapy, some authors believe that there is indication for radical resection or even total pancreatectomy. Such procedures have been done in a number of patients at other surgical

TABLE 6
CHRONIC RELAPSING PANCREATITIS
Hospital of the University of Pennsylvania, 1932-1949

Patient	Age and Sex	Epigastric Pain	Calcification in Pancreas by X-ray	Diabetes	Pancreatic Enzymes in Duodenal Drainage	Operation	Result
W.F.	46M	3 yrs.	Yes	1½ yrs	Not done	Partial pancreatectomy	Incomplete relief Died 10 months
J.T.	34M	2 yrs.	Yes	6 yrs	All below normal	Bilateral lumbo dorsal sympathectomy	Pain relieved
W.D.	62M	2 yrs.	Yes	Diabetic sugar tolerance curve	All below normal	Total pancreatectomy	Pain relieved
TRAUMATIC PANCREATITIS							
G.S.*	40M	8 mos.	No	Diabetic sugar tolerance curve		Multiple explorations with drainage of pancreas and gallbladder	Died of endocarditis

* Previously reported by DeMuth and Rawson²¹

clinics with complete relief of pain to prove the efficacy of the operation. In the case of this patient, during the third year of his disease, he was again explored and we resected the tail and body of the pancreas. This afforded but incomplete relief. Before the symptoms had become severe enough to lead us to complete the pancreatectomy, the patient developed a gastrojejuno-colic fistula of which he died.

Before another case of this type was encountered, Rienhoff and his associates⁴ had reported relieving such a patient by interruption of the greater and lesser splanchnic nerves, the sympathetic chains, and both vagi. The plan of this procedure is to render the patient incapable of feeling the pain arising in the pancreas. With a thoracolumbar sympathectomy alone, Smithwick⁵ in 1946 demonstrated complete relief of

pain in a patient with multiple calcareous deposits. Subsequent studies by Ray and Neill,⁶ and by Grimson and his associates⁷ have confirmed the value of such a procedure. In some instances, such a resection only on the right side has been sufficient. Doctor Ray recently stated that it was sufficient to resect from

lesser splanchnic nerves on bo

relief obtained by the use of

as a diagnostic procedure and in several cases has advised the use of splanchnicectomy provided the patients obtained relief with repeated injections of the splanchnic nerves. Benefits from such an approach to the problem are that the procedure is of far less immediate hazard than radical resection and does not carry with it the certainty of diabetes that is caused by a total pancreatectomy.

In June 1947, another patient presented with a diabetic sugar tolerance curve, calcification in the pancreatic area, and recurrent attacks of pain which had plagued him for five years. He had had a cholecystectomy two years earlier by a very experienced surgeon who noted thickening of the head of the pancreas at that time. Duodenal intubation revealed almost complete absence of pancreatic amylase, lipase, and trypsin. On the basis of this evidence, we felt sufficiently sure this patient had chronic relapsing pancreatitis to omit biopsy and to do a right dorsolumbar sympathectomy two months later. Improvement was transient and a left lumbodorsal sympathectomy was necessary. Since then, the patient has been free of pain and has been able to give up the use of narcotics.

Opponents to the use of sympathetic surgery for the relief of pain for chronic pancreatitis believe that it should be reserved for those patients in whom the inflammatory process is in the end stage of calcification. Otherwise, exacerbations of the disease may go unnoticed after this procedure and it is not unknown for a patient to have bouts of fever attended with slight tenderness on pressure as the result of development of pancreatic infection or necrosis, but to have no spontaneous pain because of the sympathectomy.

In many of these patients, a diabetic tendency is already demonstrable and the external secretion of the pancreas is greatly reduced in its enzyme activity, so that there is not much to be lost by sacrificing the entire pancreas. After total pancreatectomy the insulin requirement is considerably lower than that of some severe diabetics. In Whipple's review⁸ of fourteen cases of total pancreatectomy together with three subsequently reported cases,^{10, 11, 12} the average insulin requirement was 32 units. Hypothetical calculations based on experiences with depancreatized animals by various investigators before the development of modern pancreatic surgery varied from 70 to 300 units for the average theoretical requirement to maintain normal carbohydrate metabolism in man. This discrepancy remains unexplained. Owing to the absence of pancreatic enzymes after total pancreatectomy, digestion and absorption of fat and protein are moderately impaired. The administration of pancrea-

tin as a substitute for pancreatic juices is helpful but is not always completely effective.

In February 1948, a total pancreatectomy was carried out in a man of 62 years, who had classical symptoms and findings of chronic relapsing pancreatitis. The operation was made difficult by an extreme degree of fibrosis around, as well as in, the pancreas. In this case it required six and a half hours. The postoperative course was extraordinarily interesting. After a stormy period of four days, during which time it was necessary to increase the insulin intake to over 100 units, the patient improved and the insulin requirement was stabilized at about 45 units. Gastric acidity was low. The depancreatized patient tends to develop a fatty liver unless choline or some other lipotropic substance is given, so choline was started by mouth on the eighth day, 1 gm. per day. Several days later, pancreatin, 15 gm., was started and on this regimen the patient had normal appearing stools and gained some in weight.

It is evident that there are several methods of meeting the problem of chronic relapsing pancreatitis; the first, to interrupt the afferent nerves and let the pathological process alone as by thoracolumbar sympathectomy, or successful regional splanchnic blocks followed by splanchnicectomy; the second, is to resect the pancreas. A third possibility is the ligation of the pancreatic ducts. Cattell¹³ believes that much pancreatic pain is due to distention of the duct and has suggested anastomosis of the duct of Wirsung to the jejunum. More experience and a satisfactory postoperative follow-up over a long period of time will be needed to evaluate these methods, but at present sympathectomy or splanchnicectomy appears to be the more conservative approach.

PANCREATIC CALCULI

Pancreatic calculi usually occur in persons past 40. As they are usually composed of calcium carbonate deposits, they are radiopaque but may be misdiagnosed as calcified mesenteric nodes, phleboliths or gallstones. The pain produced is usually epigastric with reference to the back at about the eighth dorsal segment and is commonly intermittent. Pancreatic calculi are often associated with chronic relapsing pancreatitis, in which disease calcium is laid down in approximately half of the cases either in the parenchyma as regions of calcification or in the ducts as stones. The calculi are usually multiple, may appear in the head, body or tail of the pancreas, or the entire organ may be outlined.

Undoubtedly, pancreatic calculi account for occasional instances of the so-called postcholecystectomy syndrome. So far as we know, they are not frequent in patients with acute hemorrhagic pancreatitis. In the series we have reviewed, calculi were encountered seven times. In three of these patients, they were associated with the clinical picture of chronic relapsing pancreatitis. While it is unusual to be able to remove the smaller stones at operation, the removal of the stones located in the larger ducts is usually accomplished by cutting across the parenchyma of the pancreas to the duct of Wirsung.

CYSTS OF THE PANCREAS

Pancreatic cysts are of two main types—the true cysts arising from

with a high titer of pancreatic enzymes. During the 1937 to 1949 period, we have had six examples of the true cyst and two of pseudocysts. The largest of these true cysts was about 7 inches in diameter and arose in the body of the gland. We have also had one patient with a cystadenoma of the acinar cells. This was resected. That pancreatic cystadenomas are rare is substantiated by the recent review of Benson and Gordon¹⁴ who were able to collect only twenty-eight surgically explored cases, including one of their own, from the literature. Of these twenty-eight cases, complete excision of the tumor was accomplished in twenty-one cases with an operative mortality of 20 per cent.

Of the two pseudocysts, one was a classical case in which the leader of an itinerant Scotch clan was shot in a feud. The bullet went through his abdomen and he was taken in shock to a private hospital in the vicinity where, after several transfusions, he rallied but ran a febrile course with pain in the lower chest and signs of fluid in the left pleural cavity. Over a period of five weeks, a large mass developed in his left upper quadrant and it was for this reason that he was transferred to Philadelphia. At operation, more than 4 liters of watery fluid were drained from the cyst which occupied the lesser omentum. The edges were marsupialized and the tract drained for sixteen months.

In the case of the true cysts, complete excision is usually desirable. Frequently this necessitates amputation of the left side of the pancreas. When large, however, these cysts are sometimes marsupialized and, while this is a procedure of second choice, it often works satisfactorily and may be wiser than the acceptance of the risk of a very difficult surgical procedure. The walls of the cysts may be painted with one of the destructive chemical agents in the hope of killing the excretory cells lining the cysts. Of the six cases of true cyst encountered, all were excised completely except one large one which was intimately attached to the superior mesenteric vein. After injuring and repairing the vein twice in an effort to separate the cyst completely, it was decided that the risk of irreparable injury to the vein was so great that it would be better to leave a small portion behind. This area was drained for several months and caused no trouble in the subsequent three to four years. Eventually, however, fluid reaccumulated and had to be drained again. These nine lesions have been resected (seven) or marsupialized (two) without fatality.

CARCINOMA OF THE PANCREAS

The subject of pancreatic carcinoma has received so much attention lately that everyone is more or less familiar with the recent develop-

ments. It is the chief indication at present for total pancreatectomy. While the operation is being carried out quite widely, it cannot be said to be fully evaluated as yet. When Whipple collected the available experience with it in 1941, the longest survival had been under three years. Since then, there have been a few cases with survival for longer periods, but it is still too soon to state that the operation is curative. Certainly, for the vast majority of patients, it must be regarded as palliative.

There is a growing opinion that radical resection should be reserved for ampullary malignancies without extension or very carefully selected cases of carcinoma of the pancreas where there is no infiltration of adjacent blood vessels or metastases to regional lymph nodes. In the experience of Cattell and Pyrtek (15), who recently reported sixty-one examples of pancreatoduodenal resections, including fifty-six for carcinoma (representing an operability rate of 34 per cent) and five for benign disease, there was a 5 per cent operative mortality for ampullary carcinoma as contrasted to a 16.7 per cent mortality for patients with carcinoma of the head of the pancreas. Follow-up studies of those surviving the operation revealed that 25 per cent of the patients with carcinoma of the ampulla of Vater without extensions were living and well after five years and 50 per cent were living three years or more following resection. Of the patients with carcinoma of the head of the pancreas, however, only one patient out of thirty survived three years or more.

The difficulty in removing the pancreas lies largely in the arrangement of its blood supply and in its relations with the duodenum, common bile duct, and the radicals of the portal vein. The head of the pancreas shares its blood supply with the duodenum through the superior and inferior pancreaticoduodenal arteries, and the body and tail of the pancreas derive their blood supply chiefly from the splenic vessels which lie along the superior margin of the gland and sometimes appear to be within its substance. Total pancreatectomy, therefore, requires sacrifice of the duodenum, the lower part of the common bile duct, and frequently of the spleen, though careful dissection and the ligation of numerous branches may enable one to dissect the tail and body of the pancreas away from the splenic vessels, leaving them intact.

The most difficult part of the operation is often the dissection of the gland from the superior mesenteric vein prior to its junction with the splenic vein to form the portal. The neck of the pancreas lies on top of this vessel, but the head curves around it and the uncinate process may actually lie behind it. This part of the operation should not be undertaken unless one is prepared to suture lacerations of the portal vein at points where small tributaries enter it from the substance of the gland and are at times torn off even with careful dissection.

One of the really difficult decisions at times is to know whether an area of induration in the head of the pancreas represents carcinoma or the fibrosis of chronic pancreatitis. In some instances, frozen section may

be of help, but the pancreas is not an easy organ from which to get a representative biopsy and usually the decision has to be made largely on the gross findings.

As most carcinomas are in the head of the pancreas (55 to 70 per cent), surgeons have generally been content to remove only this area. Usually there is ample islet tissue in the remainder to prevent diabetes. There is some disagreement as to whether or not the pancreatic duct should be anastomosed to the jejunum along with the biliary tract and the stomach. In the original Whipple operation, this was not done, but it has since become increasingly common to do it. Brunschwig, however, takes the point of view that the acinar tissue of the gland degenerates even if the duct is anastomosed to the jejunal mucosa and he does not believe that it is a worthwhile step.¹⁶

In all large series there has been considerable mortality. Yet, the operative risk has been steadily reduced in the last five years. In 193 cases of radical operations from five different surgical clinics, including sixteen total pancreatectomies, not all for carcinoma, the over-all post-operative mortality was 30.8 per cent.¹⁷ Evaluation of survival rates, however, differentiates the more optimistic results according to the location of the lesion. The experience of Cattell,¹⁸ the Mayo Clinic group¹⁸ and others has led them to believe that pancreatoduodenal resection may cure carcinoma of the ampulla of Vater in an appreciable number of cases, but not carcinoma of the head of the pancreas. Results of survival in the latter have been disappointing and necessitate either modification of the operative procedure or abandonment of radical surgery.

ABNORMALITIES OF THE ISLANDS OF LANGERHANS

Among the most interesting disturbances of the pancreas are those that lead to hypoglycemia, namely *adenoma* of the islet cells of Langerhans, *carcinoma* of the islet cells of Langerhans, and a *generalized hyperplasia* of the islets. It must be remembered that the pancreas does not account for all cases of hypoglycemia. Severe liver damage may account for some cases and disease of the adrenals or the pituitary may account for others. A good classification of spontaneous hypoglycemia has been made by Conn.¹⁹

The usual history of these cases is that the patients develop convulsions especially in the early morning before breakfast or that they develop abnormal behavior reactions upon fasting (Table 7). Thus one of our patients was first considered ill by his family when he woke up in a dazed way and threw his gold watch out of the window. Not a few of these cases have been found in institutions for epileptics.

In the University Hospital series, there have been six cases of which one was malignant. Carcinoma of the islet cells is a rare condition of which only about thirty-seven cases have been reported. In our case the patient succumbed with metastases but did not have hypoglycemia. The other five cases have been followed and the patients are doing well

from the standpoint of the blood sugar level. We were recently able to repeat the six hour glucose tolerance tests on all five of these patients and all were within normal limits after periods of from three to thirteen years, respectively.

The diagnosis in these cases should be suspected whenever people develop abnormal weakness, convulsions, personality change, or periods for which they have amnesia upon fasting. A blood sugar at such a time is usually below 50 mg. per cent. The glucose tolerance test shows a low peak and an early return to normal or subnormal levels. Liver function tests are usually near normal.

TABLE 7
ISLET CELL ADENOMAS OF THE PANCREAS
Hospital of the University of Pennsylvania, 1935-1945

Patient	Age and Sex	Lowest Blood Sugar	Symptoms			Operative Findings	Follow-up
			Peculiar Behavior	Drowsiness or Unconsciousness	Convulsions		
B M.	34 M	39	Yes	Yes	Yes	1.5 cm adenoma near tail of pancreas	Well. Sugar tolerance curve normal 12 yrs. later
G A	32 F	22	No	Yes	No	2.5 cm adenoma near tail of pancreas, 2 smaller adenomas from head and body	Recovering from recent gastric operation—6 yrs later
E.P.	41 M	25	Yes	No	No	3 cm adenoma with cyst formation in head of pancreas	Under treatment for tuberculosis—4 yrs later
J R.	39 M	29	No	No	Yes	4.5 cm. adenoma in tail of pancreas	Well. Sugar tolerance curve normal 4½ yrs later
M G	54 F	28	No	Yes	No	5 cm adenoma 1 cm from tail of pancreas	Sugar tolerance curve within normal range; mild symptoms of autonomic nervous system

If there is no evidence of Simmonds' disease or disease of the adrenals, exploration should be done in such cases—preferably through a transverse incision across both recti about an inch above the umbilicus. The head of the pancreas is exposed by reflecting the hepatic flexure and then mobilizing the duodenum. The rest of the pancreas is exposed by dividing the gastrocolic omentum so that the lesser peritoneal cavity is widely exposed. The posterior parietal peritoneum along the lower border of the pancreas may then be incised as it is usually avascular. This permits the surgeon to introduce his fingers behind the pancreas and palpate it carefully against his thumb or against the fingers of the other hand. In obese and emphysematous individuals, it is sometimes difficult to

reach the tail and this can be facilitated by reflecting the splenic flexure of the colon downward and, if necessary, bringing the spleen forward and supporting it with a pack.

Even if an adenoma is readily found, one should expose the entire pancreas, as multiple islet cell adenomas occur in 14 per cent of cases. If no lesion is found, a biopsy should be taken for frozen section. If the pathologist finds hyperplasia of the islet cells, some surgeons do a subtotal resection of the pancreas. The wisdom of this procedure is not yet well established.

During the preoperative period, even patients with adenoma must be evaluated for diabetic symptoms which may supervene, due to a suppression of function of the remaining islet tissue. In the patients who have undergone adenectomy, any such symptoms will usually prove transient but, in those who have had subtotal resection, the results are, of course, variable.

One should note that malignancy of islet cell adenomas is difficult to recognize on section. The presence of blood vessel invasion does not necessarily indicate malignancy. Whipple and Frantz²⁰ have established an intermediate classification of suspiciously malignant islet cell tumors in which histological evidence of malignancy exists, but clinically the tumors appear to be benign in that no metastases occur and the patients remain well following excision. At the time the first of these cases was operated on at the Hospital of the University of Pennsylvania, this was not well known. In an effort to relieve diabetes in another patient, a graft from an adenoma was implanted in her rectus abdominis muscle as soon as the frozen section was reported benign. Subsequently, the pathologist found blood vessel invasion and reported possible malignancy. The graft apparently did not take, and the subsequent course of the patient, as well as further study of his tumor, convinced us that the lesion was benign.

The results of removal of islet cell adenomas are excellent. Complete and immediate restoration to health is the rule.

ECTOPIC PANCREATIC TISSUE

Ectopic pancreatic tissue was resected from the wall of the duodenum in three patients at the Hospital of the University of Pennsylvania. In one of these, a benign ectopic nodule was resected in the search for the primary site of a malignancy which had been established by lymph node biopsy.

CONCLUSIONS

1. Evidence is presented suggesting that edematous pancreatitis and necrotizing pancreatitis may be stages in the same disease.

2. The question of whether operative or nonoperative treatment is to be preferred in the severe forms of acute pancreatitis has not been answered. Results have improved with better methods of therapy and

have been very favorably influenced by penicillin. Since 1945, we have employed operative treatment in all of the severe cases of pancreatitis with an over-all mortality of 3.2 per cent. The results are reported for possible comparison with series treated by nonoperative means.

3. Chronic relapsing pancreatitis, while not a frequent lesion, is worthy of more attention than it has received. Where stones are present in the duct, some relief may be afforded by their removal. Most cases have been treated surgically either by pancreatectomy or by bilateral lumbodorsal sympathectomy which interrupts the afferent nerves. The latter is the more conservative procedure, even though it requires multiple operations, but further experience will be required to determine which procedure yields the best results over prolonged periods, or whether one of the newer procedures will prevail.

4. Pancreatic cysts should be excised if technically possible. Pseudocysts of the pancreas and rare true cysts may have to be marsupialized.

5. Resection of the pancreas for carcinoma arising within the organ is worthwhile as a palliative procedure but so far offers very little chance of cure.

6. Pancreatic lesions are not the only causes of hypoglycemia but are among the most amenable to treatment.

Hyperinsulinism may arise in three ways: adenoma of islet cells, carcinoma of the islet cells, or hyperplasia of the islet tissue.

The common cause is adenoma and adenectomy gives complete and usually lasting cure if all adenomas are found and removed.

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RECENT ADVANCES IN KNOWLEDGE OF BONE

Contributions Applicable to Surgery

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Recent advances in the surgery of bone have derived chiefly from discoveries made in the fundamental medical sciences during or just prior to World War II. Chemotherapeutic and antibiotic agents became available just at the time when the war began to produce an enormous number of casualties and thereby provided a testing ground for new surgical methods. The incidence of spreading infection and septicemia following open fractures was greatly reduced in World War II (as compared to World War I) primarily as a result of these drugs. By employing the antibiotics, whole blood and plasma, and newer skin grafting methods, surgeons were able to perform extensive bone grafting procedures soon after the wound had healed, with a low incidence of infection. The need for large amounts of bone for grafting led to further investigations of homogenous bone transplants and to the establishment of bone banks—a development that will extend the scope of bone surgery.

The search has continued for a metal for internal fixation of bone, which is completely inert in the body tissues and also possesses ideal mechanical and physical properties. Knowledge of the advantages and limitations of existing metals has been extended, chiefly through studies instigated by the Committee on Fractures and Other Traumas (now Committee on Trauma) of the American College of Surgeons.

The constant search for a safe method of treating fractures that will effect complete fixation of the bone fragments while allowing complete mobilization of the rest of the body led to the introduction of intramedullary nailing for fractures of long bones. First used on a large scale by the Germans in World War II, the method has only recently gained recognition in America. Although the advantages and limitations of intramedullary nailing have not been fully determined, the work should enlarge our understanding of bone physiology.

Recent studies have shown that severe derangements in metabolism accompany bone injury and that patients who suffer trauma to bone are in need of nutritional treatment as an adjuvant to operation.

In this paper an attempt will be made to discuss briefly the above developments.

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BONE GRAFTING AND THE BONE BANK

The science of bone grafting has developed steadily over many years. *Heterogenous grafts*—e.g., beef bone, ivory, cow horn—have been unsuccessful, autogenous transplants have uniformly given the best results. Both cortical and cancellous bone grafts have been widely employed, the cortical graft taken usually from the tibia and the cancellous graft from the ilium. Cortical grafts must be used when stability is required, cancellous grafts show greater osteogenetic powers. The use of the latter has increased in recent years.

The fate of the grafted bone has been widely disputed. It is now generally accepted that most of the elements of the bone die and are replaced by living bone. After extensive experimental and clinical studies, Abbott and his co-workers¹ concluded that the mature elements of both cortical and cancellous bone die following transplantation. They said, however, that the cells of the endosteum and periosteum *may survive and produce new bone*. A cortical graft has little osteogenetic power because it is composed principally of mature elements. The cancellous graft, on the other hand, has a loosely woven structure; it contains many osteogenetic cells and has high powers of osteogenesis. For ununited fractures and for bridging defects of bone, Abbott stated that the best results are produced when cancellous bone is added for osteogenesis to the cortical bone necessary for stability.

Bishop, Stauffer and Swenson² reported 580 bone grafting operations performed in an army general hospital. The massive onlay graft fixed by metal screws was preferred to inlay grafts. Cancellous bone chips were added to the onlay graft to stimulate osteogenesis. It is generally advised that the incision for bone grafting be made as far away from the wound as possible, so that healthy, full thickness skin may be re-
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Phemister⁴ has recently reported a method of bone grafting that does not involve excising the fibrous union or anchoring the graft with plates or screws. The bone is exposed, the periosteum reflected, and a shallow bed for the graft is made by chiseling out a thin depth of cortex. A graft of cortical bone is inserted into the shallow bed and fixed by suturing the periosteum over it. Phemister stated that the advantages of the method are: the preservation of the fibrous union (which may aid in the formation of bone); the relative simplicity of the operation; and the elimination of metals for internal fixation. The method cannot be used when much loss of bone has occurred or when there is much instability at the fracture line. In these instances, the cortical graft must be securely fixed in order to achieve stability.

Homogenous Bone Grafts and the Bone Bank.—Autogenous bone is

considered the ideal type of graft, but many instances arise in which autogenous bone cannot be safely acquired in sufficient amounts: e.g., in extensive bone operations on children, in patients with considerable bone loss, and in poor risk patients. During World War II, when many of the wounded had extensive bone destruction, surgeons were induced to experiment further with the homogenous bone graft.

The transplantation of bone from one person to another or from one species to another has been tried from the middle of the nineteenth century. Heterogenous grafts were never satisfactory. In 1942 Inclan,⁵ after experimental work on rabbits and dogs, reported the results of nine human homogenous grafts. The grafts were covered with the citrated blood of the donor and refrigerated at a temperature of 2° to 5° C. Inclan concluded that the homogenous transplants acted like fresh autogenous bone, even though preserved for as long as three weeks.

Many subsequent investigators have found homogenous bone transplants to be successful. Henry⁶ used homogenous chip grafts of cortical bone with good results. The graft was taken from a donor who was a close relative of the patient (syngenesioplasmic graft) and of the same blood type. Bush and Garber^{7, 8} experimented with homogenous grafts in rabbits and reported that, although autogenous grafts were reconstituted into bone slightly more rapidly, the homogenous grafts were entirely satisfactory. They subsequently established a bone bank for human transplants at the New York Orthopedic Hospital. For this bank they used bone grafts taken from the ilium or tibia, placed in bottles, and usually frozen at minus 25°C. The bone, which was always taken from living sources, was kept at least two weeks before being used. No attempt was made to employ donors of the same blood type as the recipient, but all donors were first proved to be free of syphilis, malaria and chronic infection. Bush and Garber reported 126 operations on 104 patients and were enthusiastic about the results.

Wilson⁹ described the bone bank maintained at the Hospital for Special Surgery in New York, where homogenous grafts were used for joint fusions, treatment of ununited fractures, and for filling bone cavities resulting from the excision of benign bone tumors and cysts. The donor bone was frozen while still moist, placed in sterile sealed jars, and kept in a deep freeze unit at minus 10° to 20° F. Homogenous bone from forty donors was inserted into twenty-five patients without regard to blood groups. No massive grafts were used, the grafts were applied chiefly in the form of bone chips. Excellent results were obtained.

Successful results from the clinical use of homogenous grafts have also been reported by others.^{10, 11, 12} It is not yet proved that homogenous bone will retain living elements as well as autogenous bone. As long as the latter is the ideal bone for grafting, homogenous bone should be used to supplement rather than to supplant it. Yet the use of homogenous bone has been an important advance, and the establishment of bone banks has extended the scope of bone surgery. It is probable that banks will be set up in many communities during the next few years.

Bone for grafting has, up to the present time, been obtained from living sources. With proper organization, it may be possible for operating teams to obtain considerable amounts of bone under aseptic conditions from fresh cadavers who died from trauma. It is apparently not necessary for the donor to have the same type of blood as the recipient.

THE ANTIBIOTICS AND SURGERY OF BONE

Certain aspects of bone surgery have been revolutionized by the introduction of the antibiotics (see Table 1). In infections of bone, surgery can be performed much more safely and is sometimes eliminated altogether by appropriate use of the antibiotics, especially penicillin which is unusually effective against the principal bacteria found in osteomyelitis, namely hemolytic *Staphylococcus aureus*, hemolytic streptococci, and pneumococci. Penicillin has also decreased the risk of infection in clean operations on bone, and its prophylactic use has become widespread.

Acute Hematogenous Osteomyelitis.—In 1943 Florey¹³ said, "The evidence is that with adequate dosage it is possible to eliminate all infection, and one may look forward to the time when osteomyelitis treated early will no longer be a surgical condition." Experience in subsequent years has borne out Florey's predictions. Acute hematogenous osteomyelitis has been much less frequent in recent years because the ear and skin infections which are its usual predisposing cause are usually controlled by the liberal use of penicillin. Once acute hematogenous osteomyelitis does develop it shows remarkable response to penicillin.

Altemeier and Wadsworth¹⁴ reported seventy-one patients with acute hematogenous osteomyelitis studied over a four year period. They found "spectacular control of bacteraemia, local infection and metastatic complications." They stated that emergency surgery, once considered a life-saving procedure in certain cases of acute hematogenous osteomyelitis, is no longer necessary and there is always time for proper preparation of the patient. If penicillin is begun early in the disease, surgery may be eliminated altogether. For penicillin to be most effective it must be started during the first few days of infection. Since the roentgenographic signs do not appear until after the first week, penicillin must be started on clinical signs alone. Altemeier and Wadsworth stated that even if bone necrosis has occurred, surgery might not be necessary; according to a study of the roentgenograms, spontaneous absorption of involved necrotic bone often took place. Follow-up studies of the patients of Altemeier and Wadsworth's series showed only nine recurrences in sixty-seven patients. In each of these instances¹⁵ penicillin had been given too late or in The dose advised was up to 100,000 units a day in severe infections. Penicillin was continued for at least one week after all signs of infection had disappeared.

Trueta and Agerholm¹⁵ and Nachlas and Markheim¹⁶ also reported excellent results from penicillin in acute hematogenous osteomyelitis. Trueta and Agerholm advised surgery if pus is present in the medulla or subperiosteal space, but they waited twelve to forty-eight hours before operation. The operation consisted of drilling holes in the bone instead of making a window in the cortex. Wounds were routinely closed without drainage.

It is not universally believed that penicillin has abolished the need for surgery in all instances of acute hematogenous osteomyelitis. Dick-

TABLE 1
EXAMPLES OF THE EFFECT OF PENICILLIN ON SURGERY OF BONE

	Before Penicillin	After Penicillin
Mortality of acute hematogenous osteomyelitis	25% \pm (a)	2% \pm (b)
Surgery for acute hematogenous osteomyelitis	Usually necessary (a, b)	Often not necessary if treatment is begun early (a, b)
Loss of bone grafts from infection (battle casualties)	17%, World War I (c)	3.3%, World War II (d)
Time advised between healing of infected open fracture and graft- ing procedure	1-2 years (e)	6 weeks to 6 months (e)
Saucerization of chronic osteo- myelitis with primary wound closure, with or without plastic procedures	Generally unsucces- ful (f, g, h)	Generally success- ful (f, g, h)

Sources: (a) Altemeier, W. C. and Wadsworth, C. L.¹⁴

(b) Nachlas, I. W. and Markheim, H. R.¹⁶

(c) Kirk, N.²⁰

(d) Bishop, W. A. et al.³

(e) Lambert, C. N.²¹

(f) Buchman, J. and Blair, J. E.²²

(g) Reynolds, F. C. and Zoepfel, F.¹⁸

(h) Sherman, M. S.¹⁹

son¹⁷ said that surgery supplemented by penicillin is less dangerous than surgery alone and abscesses can be drained with greater safety. Dickson pointed out that the chances of recurrence are decreased by early surgical removal of the nidus of infection combined with large doses of penicillin.

There is no doubt that penicillin has decreased the incidence of acute hematogenous osteomyelitis. There is also general agreement that if penicillin is given early in established acute hematogenous osteomyelitis it may cure the disease before bone necrosis takes place. But surgeons disagree on how often surgery is needed and how extensive it need be in the presence of bone necrosis.

Chronic Osteomyelitis.—Chronic osteomyelitis has not responded as dramatically to penicillin as has acute osteomyelitis.^{18, 19} Penicillin alone is rarely sufficient, the infected bone must be saucerized before healing will occur. Penicillin, however, is a powerful adjunct to surgery in chronic osteomyelitis because it permits radical surgery with less risk than formerly of spreading infection and septicemia. Plastic procedures for filling the cavities in bone following saucerization (e g., use of muscle flaps, packing with bone chips) can be performed with little risk of infection, and the wound can usually be closed with impunity.

Following surgery for chronic osteomyelitis it is best to cover the bone with full thickness skin. If enough skin is not available, a split thickness skin graft can be closely applied to the bone cavity. When a large skin pocket results from this procedure it should be filled with cancellous bone chips at a second operation (a scar-filled pocket often leads to vascular changes and necrosis) and then covered with full thickness skin.

Penicillin in the Prophylaxis of Bone Infection.—The striking effect of penicillin in reducing infection following extensive bone surgery in battle casualties is shown by a comparison of the results of bone grafting procedures in World War I and World War II. Kirk²⁰ stated that, in World War I, 17 per cent of his bone grafts in battle casualties were lost from infection. In the last war Bishop, Stauffer and Swenson² lost only 3.3 per cent of grafts from infection.

The use of penicillin has sharply decreased the necessary delay between the healing of the wound in open fractures and bone grafting. Whereas previously the established practice was to wait one to two years, bone grafting is now often performed within six weeks after healing.²¹ It has been found that cancellous bone is more viable in the presence of infection than cortical bone—especially if penicillin is used.¹

Penicillin is effective in reducing the incidence of postoperative infection in clean bone operations. Buchman and Blair²² concluded that "intramuscular administration of penicillin for twenty-four hours before an operative procedure on bones and joints and for about ten days after constitutes a dependable method for the avoidance of ordinary surgical infections which have plagued patients and embarrassed surgeons from time to time".

Some surgeons have disparaged the employment of penicillin prophylactically because they think it gives a "false sense of security" and thus tends to make the surgeon "careless in his technic." From the point of view of the patient it seems almost inhuman to withhold penicillin for the purpose of forcing the surgeon to perform an adequate operation. Antibiotics should increase the scope of surgery, not encourage poor technic.

Streptomycin and Tuberculosis of Bone.—Recent reports^{23, 24, 25} have shown an increasing confidence in the usefulness of streptomycin in the treatment of bone and joint tuberculosis. Although the results are not as dramatic as in intestinal tuberculosis, a slow but definite

improvement has been reported in the majority of patient. Bickel²³ recommended 1 gm. daily for ninety days. A longer period of study is needed before the value of the drug can be accurately determined.

METAL FOR THE INTERNAL FIXATION OF BONE

The proper treatment of injured bone often necessitates internal fixation with metal, although the use of any known foreign material carries some risk. Scientists have long sought an ideal metal for internal fixation: one that is inexpensive, possessed of ideal physical and mechanical properties, and completely inert in the body tissues. Although several adequate metals have been developed, all of them have drawbacks.

Only recently have metals been developed that are sufficiently inert in the body tissues. Venable and Stuck²⁴ found that many metals were poorly tolerated because of the electrolytic activity about the metal,

TABLE 2
COMPOSITION OF VITALLIUM

Cobalt	65 per cent
Chromium	30 per cent
Molybdenum	3 per cent
Manganese	q.s.
Silicon	q.s.
Carbon	q.s.

(From Kennedy, R. H.: Bone Plates and Screws Symposium on Fractures and Other Traumas. Clinical Congress, American College of Surgeons, Sept. 9, 1947, New York)

resulting in "electrolytic osteitis." Experiments performed by them in 1936 showed that all of the metals then in common use in surgery caused damage to tissues because of electrolytic activity. The extent of tissue damage was roughly equivalent to the galvanic action that took place between the metals. They found that if a combination of metals is inserted at a single operation, an electromotive force is set up between the metals, and osteitis results. Venable and Stuck discovered that a dental alloy, vitallium, was completely inert in body fluids, and after experimental and clinical trials they recommended it for clinical use. The composition of vitallium is given in Table 2.

In 1940 the Committee on Fractures and Other Traumas appointed a subcommittee to study the metals available for internal fixation of bone.^{26, 27, 28} This committee initiated a series of investigations which were carried out at Columbia University by Professor Colin Fink of the Engineering Department and Dr. Clay Ray Murray of the School of Medicine. From these studies it was concluded that two available metals were acceptable for use for internal fixation: vitallium and 18-8 SMO stainless steel (Table 3). Vitallium was found to be completely inert in the tissues, but the physical and mechanical strength of individual

plates showed unpredictable variations, so that there was danger of breakage. This is due to the fact that vitallium is cast, instead of cold rolled, and therefore contains large crystals. Professor Fink expressed the opinion that improvements in the manufacture of vitallium plates might eliminate this objection. 18-8 SMO stainless steel, although not completely inert in body tissues, was found to cause so little interference with healing processes as to be within physiological limits. Its physical and mechanical properties were the best of the available metals. The United States Army's specifications for plates and screws, prepared in cooperation with the National Bureau of Standards, require 18-8 SMO stainless steel (29).

The Committee on Fractures and Other Traumas has made recommendations for uniform types of plates and screws with desirable mechanical and physical properties.²⁷ These recommendations are now in

TABLE 3

COMPOSITION OF 18-8 SMO STEEL, AMERICAN STEEL AND IRON INSTITUTE SPECIFICATION 316 AND 317

Chromium	17 to 20 per cent
Nickel	10 to 14 per cent
Molybdenum	2 to 4 per cent
Manganese	2 per cent maximum
Carbon	0.08 per cent maximum
Silicon	0.75 per cent maximum
Phosphorus	0.03 per cent maximum
Sulfur	0.03 per cent maximum
Iron	Remaining per cent
Rockwell hardness	C-30 to C-35

(From Kennedy, R. H., Bone Plates and Screws Symposium on Fractures and Other Traumas. Clinical Congress, American College of Surgeons, Sept. 9, 1947, New York.)

the hands of the Bureau of Standards. It is hoped that the Bureau will be able to adopt new commercial standards so that the materials from different manufacturers will be uniform and acceptable. Thus far, Dr. L. B. Tuckerman of the Bureau of Standards, has been reluctant to write specifications for vitallium bone plates because of the impossibility of distinguishing "brittle" plates before use and the danger of subsequent breakage.²⁹

Dr. R. H. Kennedy,³⁰ chairman of the Committee on Fractures and Other Traumas, reported that in recent investigations, carried out with the aid of Dr. Tuckerman, absorption around screws was shown to be caused by improper curvature of the plate from side to side (the inside curve of the plate should be that of a penny), or by too much torque in driving the screw home, or by incorrect centering of the screw.

The search for an ideal metal for internal fixation of bone will continue. Recent experiments in this laboratory³¹ have shown that the metal zirconium is well tolerated by bone, but tests to determine its mechanical fitness have not been made.

INTRAMEDULLARY PINNING OF FRACTURES

Although for many years substances have been inserted into the medullary cavity for fixation of bone fragments—chiefly for grafting—intramedullary nailing for the treatment of fractures has been used on a large scale only in the last few years. Küntscher of Germany, after preliminary experiments on dogs, began to use the method extensively on humans in 1940.^{22, 23, 24, 25} Intramedullary nailing was widely employed by the German Army in World War II and on the European continent after the war. It has only recently begun to attract much attention in this country. The great virtue of intramedullary nailing is that it allows the rest of the body to remain mobile during fixation of the bone. It may also have uses other than in the treatment of fresh fractures—e.g., in osteotomy, and shortening of the limbs. The physiological effects of an intramedullary foreign body are of interest because of the destruction of part of the marrow. Küntscher and others stated that the presence of the nail in the medullary canal stimulated the production of callus and speeded the healing process of fractures. Böhler,²⁶ on the basis of an abundant experience with nailing, concluded that the nail often inhibits fracture healing. Experiments were recently performed in this laboratory to determine the effect of intramedullary nailing on fracture healing.²⁷ An intramedullary wire inserted into the fractured ulna of the dog was found to stimulate a periosteal reaction, often at some distance from the fracture site. This "periosteal callus" was quickly absorbed and seemed to have little effect in the healing of the fracture. Our experiments indicated that the presence of an intramedullary wire did not increase the speed of healing other than by increasing the degree of immobilization; neither did the intramedullary foreign body appear to delay fracture healing significantly.

Hazen and Santurio²⁸ compared the chemical composition of the callus formed in fractures of the dog's femur after treatment by simple immobilization with the callus formed after intramedullary nailing. Because no appreciable difference was noted in the process of mineralization between the two groups, the authors concluded that intramedullary pinning did not hinder mineralization of the callus.

Küntscher emphasizes the danger of shock from the procedure, and Böhler reports several immediate deaths from intramedullary nailing. Except in the elderly or poor risk patient, there should be no unusual danger if the patient is properly supported by good anesthesia and sufficient quantities of whole blood. One is puzzled by the many instances of shock and immediate death from nailing procedures reported by the Germans, and one wonders if fat embolism might have been responsible for these complications.

Even though antibiotics were not widely used in the German experience, infection was not common. Both Böhler and Küntscher advised leaving the nail in if infection developed. The nail affords immobilization desirable for the healing of the infection, and acts as a drain for the medullary cavity.

It is probable that intramedullary nailing should at present be used only for fractures of the shaft of the femur and certain difficult fractures of the ulna (Monteggia fractures). How widespread its use will become in this country is yet to be determined. Whatever its final place in the surgery of bone, its study should contribute to our understanding of fracture healing.

PROTEIN METABOLISM AND INJURY OF BONE

Profound changes occur in protein metabolism after extensive bone injury. By nitrogen balance studies Cuthbertson⁴³ and Howard⁴⁴ showed increases of the urinary nonprotein nitrogen for periods as long as a month following fractures. Howard found that the average loss of nitrogen in a group of patients with fractures was 225 gm. during an average period of thirty-five days. Howard could not account for this loss by fever *per se*, atrophy of disuse, or loss of muscle substance at the site of injury. He postulated that it was related to the effects of the products of devitalized tissue on general body metabolism. The establishment of a positive nitrogen balance in these patients by high protein, high caloric diets has been difficult. Cuthbertson found that most of the extra nitrogen administered appeared in the urine. It is possible that substances now unknown must be replaced before a positive nitrogen balance can be effected.

The literature on the effect of trauma on protein metabolism has been recently reviewed by Braasch.⁴⁵

SUMMARY

Certain recent advances in knowledge of bone which are applicable to surgery have been briefly discussed. It appears that the surgery of bone has progressed in recent years chiefly through application of discoveries in the fundamental medical sciences rather than through discovery of new clinical procedures.

Some of these advances have been:

1. Discoveries in the physiology of bone grafting which improved clinical grafting methods and led to the establishment of bone banks
2. The development of penicillin, which has profoundly altered the surgical treatment of bone infections and has minimized infection following operations on clean bone
3. Cooperative investigations by physicians, physicists, and engineers which have led to a better understanding of the advantages and limitations of the metals now available for the internal fixation of bone.
4. Demonstration of the severe derangements in protein metabolism that occur as a result of severe trauma to bone.

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THE VALUE OF BLOOD TRANSFUSIONS

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INTRODUCTION

The transfusion of whole blood constitutes what is probably the best "shotgun" prescription we have. Intensive studies of the cells and plasma are now revealing the complexity of the substance; it is obvious that a patient receiving blood, besides benefiting from a volume replacement of cells and plasma, is the recipient of potent factors concerned in numerous vital processes. Albumin determines osmotic pressure and is vitally concerned in protein metabolism generally. The globulins also are part of the nutritional balance, and the alpha globulins contain the immunologic principles. Fibrinogen, prothrombin and platelets are part of the clotting process. The fundamental chemical qualities include consideration of oxygen and carbon dioxide exchange, iron metabolism, the functions of the sodium and potassium ions, fluid, electrolyte, and acid-base balance, to mention only a few. Studies of the components will eventually result in the availability of specific substances for many specific disorders, as at present albumin, fibrin products, convalescent sera, resuspended red blood cells and plasma are used. But there remain quite specific indications for the use of the entire shotgun charge; and there are other indications which, while not truly specific, are definite and satisfactory in so far as the extraneous elements are known to do no harm.

Technical Aspects.—The technical aspects of blood transfusion have been greatly simplified within the past twenty years. Closed methods of obtaining blood from donors have all but done away with the scrubbing, masking and gowning which used to accompany the "operation" of transfusion. Efficient blood preservation solutions have rendered storage safe for longer periods, and the use of disposable equipment has minimized the pyrogen problem. The advances in the understanding of blood grouping and subgrouping, especially in regard to the Rh factor, have further reduced unexplained reactions, so that reaction rates now are very low. Transfusion of blood, with routine precautions, is now quite safe, and where the indications are clear cut, the risk is negligible.

Cautions.—Perhaps it would be well to insert here a few comments in regard to certain cautions in the use of whole blood. Safety of transfusion depends upon constant attention to details. There is a definite mortality connected with the procedure. In the presence of leukemia, certain hemolytic jaundices, and high fever, reactions occur which are

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severe and may result in disaster. The possibilities of the human element with respect to mislabeling tubes and flasks must be constantly kept in mind. Reactions masked by anesthesia are little understood. Reported reaction rates are almost certainly too low. All of which means that transfusion of blood, although carried out routinely and simply at present, is not without some risk, and should never be performed without specific indications.

Blood Banks.—The need for large amounts of blood has resulted in widespread use of blood banks, the operation of which is now quite standardized. The recent war hastened the development of this phase, but it is interesting to note that Robertson in 1918 wrote of his experiences with preserved red blood cells and he conducted what must have been the first bank.¹ Rous and Turner² had described the successful preservation of red blood cells and Robertson utilized their technic for administering type O cells which had been stored up to three weeks. He noted that the benefits derived seemed the same as those from immediate transfusions. Thus the recent utilization of type O Rh-negative blood treated with Witebski's anti A and B factors represents merely a refinement of Robertson's principles of having blood available for immediate emergency use, typing and cross-matching being unnecessary.

INDICATIONS

Acute and Chronic Blood Loss.—The most obvious indication for the use of whole blood is, of course, for replacement of whole blood loss—i. e., *hemorrhage*. Hemorrhagic shock has been extensively studied both experimentally and, during the war, clinically. It is accepted now that loss of red cells and plasma is best treated by replacement of red cells and plasma, not by either alone. The inadequacies of plasma were soon discovered, resulting in a greater demand for whole blood. The value and safety of transfusions in many thousands of cases were established even before Rh typing was universally used, although it is now recognized that accidents occurred, especially in patients who needed multiple transfusions over a period of time which permitted sensitization to occur. In chronic types of hemorrhage the value of transfusion is dependent upon other factors—the urgency of replacement, planned operative therapy, and the possibility in nonsurgical cases that transfusion may depress the normal regenerative function of the marrow. Gastrointestinal hemorrhage requires preparation for the immediate availability of sizeable quantities of blood, but only in the infrequent case must these large quantities be used. Where the source of hemorrhage can be controlled before the patient is markedly anemic, there may be no indication for replacement. In general, blood loss to the outside always requires preparation for transfusion; it may or may not require the administration.

Reduced Blood Volume; Hypoproteinemia.—Chronic blood loss, the anemias of malignancy and burns, pose complicated problems in re-

placement. It is not within the scope of this paper to discuss each condition in detail. Decreased total blood volume, hypoproteinemia, secondary anemia, and electrolyte imbalance must be evaluated as to their relative importance in a given case. Measurements of these deficiencies, which determine rational therapy, are still difficult and in many instances not sufficiently accurate, but they do indicate the direction in which therapy must be carried out. In regard to the determination of blood volume, Beling, Morton and Bosch² have outlined a simplified technic which can be used by most hospitals without elaborate facilities. Approximate measurements almost always serve to indicate that large amounts of blood are indicated in true depletions. The conversion and utilization of protein, and the balance between circulation and tissue make estimates of actual deficiencies difficult to interpret; it is well known that a normal value for plasma proteins does not indicate a satisfactory condition of the tissue proteins, or even a satisfactory total amount of circulating protein. For in reduced blood volume, the grams per 100 cc. of both proteins and hemoglobin may be normal, while the grams per person of these substances are dangerously depleted. In such a case there is evidence that ingested protein, in the body's economy, goes first to the formation of hemoglobin, and only after that essential substance is sufficiently replaced is further protein available for plasma and tissue stores.⁴

In cases of gastric carcinoma, it has been found⁵ that hypoproteinemia persists following operation in the presence of body tissue repletion. Estimation of actual depletions in carcinoma cases, then, are only approximate. They are, of course, based on the individual's normal weight and estimated normal blood volume. In preoperative surgical cases, will whole blood suffice for the correction of these defects? Empirically, it is obvious to all surgeons that the extensive operative procedures now being carried out have been made possible largely by the use of massive transfusions. The immediate replacement of blood loss, the correction of decreased blood volume are obvious necessities.

That transfused plasma proteins are directly utilizable by the recipient for increasing his own plasma protein level has been shown by Allen and his co-workers.⁶ That the plasma proteins are in an interchangeable balance with tissue proteins is strongly indicated in Whipple's work. Large quantities must be used. Experimentally, Miller and his associates⁷ have not only demonstrated the utilization of infused plasma proteins but also that hemoglobin itself contributes to the body protein pool, the globin being utilized while the pigment radicle is discarded. Thus blood stored for several weeks, the red cells of which may not remain viable for long in the recipient's circulation, may still be useful for the globin (and possibly the iron) released upon disintegration of the cell.

The subject of shock is still somewhat unclear, but in most cases, therapy is granted to consist mainly in the use of whole blood. Under certain circumstances plasma alone may be indicated. After hemolytic

reactions from transfusion, there may be a definite indication for compatible blood, and the same may be true for the shock of crush syndrome, and other lower nephron nephroses, in the presence of evidence of circulatory collapse.

Summary of Indications.—Thus the specific uses for whole blood may be summarized as follows: acute and chronic blood loss; reduced blood volume; and hypoproteinemia. The first indication includes acute and chronic hemorrhage, the rapidly developing anemia of burns and severe infections, hemolytic blood loss; the second includes all conditions resulting in decrease of circulating blood volume, the most important of which is shock; and the third indication embraces the entire problem of protein balance and general nutrition.

The indications, of course, may overlap, and in the rapid preparation of many seriously depleted surgical patients, this is often the case. It is not unusual for a patient to receive six or seven transfusions of 500 cc. each prior to operation, with further replacement for loss on the table. In these patients there occur concomitantly anemia, lowered blood volume, and hypoproteinemia. Where the defects cannot be corrected by diet, transfusion offers the most direct and most rapid therapy. The future brings hope of the use of concentrated blood fractionation products to add more specificity to the therapy; and refinements in the various protein hydrolysates and mixtures of pure amino acids may some day prove to be more efficient substitutes for certain deficiencies in the blood than complete blood itself. Serum albumin is an example; its safety, specificity and effectiveness have been proved.

TRANSFUSION AS FACTOR IN OVERCOMING INFECTIONS

Closely related to the problem of nutrition, protein balance and adequate hemoglobin is the question of infection. It has been shown

that there is a direct relation between the amount of blood lost at delivery and the incidence of puerperal infection—the greater the loss the higher the incidence. Sturgis¹⁹ states that the anemia of chronic infection is refractory to all forms of therapy except removal of the cause and blood transfusion.

Surgeons during the War, without time for carefully controlled clinical experiments, from observation of thousands of cases, gained the definite impression that one of the first steps towards overcoming infection was the replacement of estimated blood loss. The treatment of severe anaerobic infections, for instance, in the general hospital with which I was associated, consisted of immediate transfusion and antibiotics. Definitive surgery came later. Far more important than the antibiotics is the capacity of the individual to mobilize the protective forces of natural and acquired resistance. "The forces are dependent, basically, upon protein metabolism, acting through the agency of amino acids

ingested in the food or readily available in tissue protein reserves".¹¹ These authors also call attention to the atrophy of liver, spleen, bone marrow and lymphoid tissue in protracted protein deficiency—organs which are concerned in the origination of phagocytic cells.

Wohl, Reinhold and Rose¹² have shown impairment of antibody response in hypoproteinemic patients, a phenomenon which had already been demonstrated in laboratory animals. It would appear, then, that the control of infection is intimately concerned in the problem of replacement of the plasma proteins and hemoglobin, and infection may constitute in some cases the more important indication for the use of blood.

OTHER CONSIDERATIONS

There are a few other considerations in discussing the value of blood transfusion. Vascular occlusion of the main vessel to a limb, from embolus, local thrombosis, or trauma, leaves the problem of survival up to small collateral channels. Anemia cuts down the efficiency of the oxygen carrying mechanism, and immediate correction of this anemia constitutes a definite indication for transfusion—perhaps preferably by red cell suspensions, if total volume is normal. In most traumatic cases of course, there is accompanying whole blood loss with the indication for replacement in kind.

Although the relationship of the actual number of platelets to the bleeding in thrombocytopenic purpura is not entirely clear, the therapeutic effect of fresh blood (platelets agglutinate rapidly in stored blood) is fairly well established. Prothrombin deficiency may be immediately corrected by the use of blood. The value of transfusion in heparin overdosage is well known. In hemophilia both whole blood and plasma will supply the deficient thromboplastin.

SUMMARY

The various indications for blood transfusion have been discussed. Until more specific substances are available, whole blood transfusions will be valuable in a variety of conditions, but their use in the treatment of hemorrhagic shock, and for rapidly replacing decreased blood volume accompanied by deficient proteins and hemoglobin will continue to be important. Blood loss and shock and poor nutrition are so much a part of surgical practice that it is no longer justifiable to submit patients to major operative procedures without the availability of sufficient blood and plasma for preoperative preparation, loss of blood in the operating room, and postoperative emergencies.

The technical aspects of surgery: . . .
physiologic considerations under . . .
rhagic tendencies, oxygenation— . . .
of equilibrium with the other tissues, are intimately connected.

Proper understanding of the available facts will point out the value of

blood transfusion, in sufficient quantities to meet therapeutic needs, and it will not result in the unnecessary use of blood. The risk of transfusion, although small, is still definite, and never justifies the indiscriminate use of the valuable substance.

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THE MAINTENANCE OF THE FLUIDITY AND COAGULABILITY OF BLOOD

Physiological and Surgical Aspects

LEANDRO M. TOCANTINS, M.D.*

Generally speaking, during most operations a surgeon would like to have the blood of his patient clot as rapidly as possible, and as slowly as possible *after* the operation. The trauma involved in a surgical procedure demands prompt hemostasis, and hemostasis is the initial phase of healing. Postoperatively, however, stagnation of the circulation resulting from the recumbency and restricted physical activity encourages thrombosis and possibly embolism.

How can a surgeon assure himself of having good hemostasis when he needs it, and of preventing or alleviating thrombosis when he fears or faces it? In order to handle such problems, the surgeon must be acquainted with the forces which make it possible for circulating blood to be at once fluid and coagulable, at the respective proper times and places. Once having a *working* knowledge of *what* enters into the mechanism and *how* it operates, he is in a better position to recognize what may have gone wrong in a given patient, and to plan rationally the steps to correct the disorder.

This discussion is intended chiefly to provide such a working knowledge for the practicing surgeon. It shall deal with moving, functional mechanisms, rather than their ultimate physicochemical nature. To go into detailed physicochemical considerations at this time, is to invite controversy and confusion, and risk incurring the disinterest of the reader without tangible gains in the practical understanding of the problem. The descriptive terms used may seem too broad if judged by the standards of the chemist; they are sufficient by physiological standards, for the description of the activities or factors concerned.

At the outset, it should be made clear that changes in the blood are only a part of the more complex mechanism of hemostasis and thrombosis.¹ Vascular and extravascular factors enter into these mechanisms and, under certain conditions, play the dominant role. A tendency to bleed may exist without detectable changes in the coagulability of blood and conversely, the fluidity of blood may be unusually high (as in hemophilia) without excessive bleeding, if the patient is exposed to ordinary stresses. Nevertheless, within the limitations introduced by the participation of

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vascular and extravascular factors, the mechanisms of hemostasis and thrombosis are unquestionably greatly influenced by the prevailing degree of fluidity and coagulability of the blood.

BLOOD "EX VIVO" AND "IN VIVO"

In our minds, most of us associate blood coagulation with the behavior of blood removed from the body and observed in tubes of glass or similar material. While some of the facts thus learned have been useful, it must be realized that blood so handled is outside of the body, away from its natural environment, the blood vessels, and often in contact with surfaces which, like glass, have a profound effect on the physical stability of blood. Caution must therefore be used in applying facts learned in this manner to conditions within living blood vessels. Circulating blood is under the following influences to which collected, "ex vivo" blood is not exposed:

- (a) A rapidly moving current which keeps any forces in a given area from affecting a certain volume of blood for more than a fraction of a second, and assures distribution of essential factors throughout the circulation.
- (b) A continuous replenishment from organs through which the blood is flowing, of materials required to maintain its fluidity and coagulability.
- (c) A surface (the vascular endothelium) which when intact aids in maintaining the blood fluid, and when damaged, releases substances which accelerate its coagulation.

In contrast, blood collected "ex vivo" is stagnating blood, at the mercy of a fixed contacting surface, having no way of replenishing its content of clotting inhibitors. Unless unusually stable, blood coagulates rapidly after being shed and brought under these conditions.

COMPONENTS OF THE MECHANISM FOR MAINTENANCE OF THE FLUIDITY AND COAGULABILITY OF BLOOD

Circulating blood contains within and about itself all that is needed both to prevent or delay coagulation and to promote or accelerate it. The fluidity of blood is maintained by a dynamic equilibrium between the two following opposing groups of factors within and in contact with the blood:

Anticoagulants

(Factors suppressing or delaying coagulation)

1. Rapid circulation
2. Intact vascular endothelium (or surfaces like silicone, collodion or paraffin)
3. Anticephalin (antithromboplastin)
4. Antithrombin
5. Fibrinolysin (as profibrinolysin)

Coagulants

(Factors promoting or accelerating coagulation)

1. Slow or stagnant circulation
2. Damaged vascular endothelium (or surfaces like glass or clay)
3. Cephalin (platelets, leukocytes, tissue cells)
4. Prothrombin, Ac-globulin
5. Fibrinogen

The rate of coagulation of blood when carefully estimated,⁶ using appropriate surfaces, reflects the state of this equilibrium. An increase in certain anticoagulant factors not compensated by a corresponding increase in coagulants will inevitably lead to greater stability of the blood and a delay in the inception of clotting. This is what happens, for example, when heparin is administered to a patient; the anticephalin and antithrombin activities of the blood are thereby enhanced and, if other factors remain unchanged, the anticoagulant effect becomes the dominant one. If, however, the number of platelets in the patient's blood were, say, 1,000,000 per cu. mm. or more, the blood (before the addition of heparin) would be hypercoagulable, and heparin, in the same doses, would serve chiefly to offset the coagulant effect of the excessive number of platelets. There would therefore be little or no change in the equilibrium between the two antagonistic groups and the rate of blood coagulation would be unchanged. This is why, when using heparin therapeutically against thromboembolic disease (as for example after a splenectomy), the dose may have to be adjusted from time to time, to offset changes in coagulant factors (platelets, prothrombin) naturally antagonistic to heparin. Otherwise, one risks giving either insufficient or excessive amounts, in either case falling short of, or beyond the therapeutic effect desired.

If an excess of an aqueous tissue extract of brain is added to 1 ml. of normal blood, its rate of coagulation may be reduced from about ten minutes to thirty seconds or less. Here the enhanced coagulability resulted from an uncompensated excess of cephalin. If, however, before the addition of the tissue extract, heparin is added to the blood in adequate amounts, the rate of coagulation may again be about ten minutes, or in other words, the equilibrium between coagulants and anticoagulants, which had been disturbed by an excess of thromboplastin, has been compensated by adding an anticoagulant (heparin) with strong antithromboplastin and antithrombin action.

Another example may help further to clarify the above concept. Dicumarol promotes the fluidity of blood by reducing its content of prothrombin, while other factors remain unchanged. This diminution in an important coagulant factor, when *unaccompanied* by an equivalent diminution in anticoagulant factors, results in a prolongation of the rate of coagulation and a greater stability of the blood. Simple prothrombinopenia, however, whether spontaneously or artificially induced, does not necessarily result in greater stability of the blood. Often, especially after a large hemorrhage, there is, either through blood dilution or other causes, besides a decrease in prothrombin an equal or greater decrease in anticoagulants (anticephalin) and an increase in the number of platelets, the combined effect resulting in an acceleration of blood coagulation, despite the low prothrombin concentration. It seems clear, therefore, that no single component plays at all times the dominant role in maintaining the fluidity and coagulability of blood. It is rather the dominance of the combined effect of one group of components over the other,

under a given set of conditions, which determines whether the blood shall remain fluid, or how rapidly it shall coagulate.

These concepts are admittedly more complex than the prevailing explanations for the mechanism of blood coagulation, concerned as the latter have been more with what happens to blood in a glass tube than in the vessels of a living being. The simple two-stage theories of coagulation such as that of Morawitz, and the currently proposed three-stage theories, tell us what makes blood coagulate; any deviations from normal are explained chiefly as resulting from deficiencies of one factor or another. The practicing physician, surgeon or clinical physiologist, faced with the pressing necessity of evolving a rational diagnosis and plan of management for a patient with a bleeding or thromboembolic disorder, has often felt insecure when using these explanations as a guide.

THE MECHANISM OF BLOOD COAGULATION

leaked into the circulation only when there has been drastic destruction of tissue and widespread cytolysis. In animals, heparin has been found in the blood after anaphylactic, peptone shock, and after extensive exposure to ionizing radiations. In man, heparinemia has been found only in patients who have received large doses of one of the nitrogen mustards.² The available evidence thus far is against heparin playing a significant role in maintaining the fluidity of the blood, under normal conditions. The anticoagulants which have been demonstrated in recent years in the circulating blood of patients with hemorrhagic disorders resembling hemophilia,³ have antithromboplastin but no antithrombin activity. Nevertheless, heparin constitutes, at the present time, our most useful tool in anticoagulant therapy. Two serious drawbacks to its wider use are its cost and the fleeting nature of its effect, making it necessary to repeat administrations at close intervals.

THE DYNAMICS OF BLOOD COAGULATION

What happens when normal blood is shed from the vessels into the tissues or on a surface like glass? Disruption of the finely adjusted equilibrium between coagulant and anticoagulant factors follows almost immediately. The changes may be separated into three phases which, though usually following one another, may obviously happen concurrently in separate portions of a given mass of blood (Fig 611).

THE PHASES OF PROGRESSION OF COAGULATION

they are no longer offset by their antagonists in the plasma (antithromboplastin).

Even after cephalin and thromboplastin are released from blood and tissue cells, the process may not go beyond the first phase, if the quantity

canalization and eventual disappearance of some intravascular clots. Such fibrinolytic agents, if free of undesirable side effects (wide proteolytic action) may some day find application in attempts to liquefy existing thrombi, and in this sense, aid in restoring the fluidity of the blood in the obstructed vessel.

MEASUREMENT OF THE RATE OF BLOOD COAGULATION

How can changes be detected in the fluidity and coagulability of the blood of a given patient? One must obviously begin by the simple measurement of the rate of coagulation. Unfortunately the multiplicity of methods used, the diverse standards and conflicting interpretations have helped to shake the confidence of the surgeon in such determinations. Conflicts in results and interpretations stem principally from these causes: (1) The use of glass tubes. (2) Defective collection of the blood; cutaneous blood obtained after a cut of the skin of a finger is unsuitable for these examinations. (3) Single determinations.

Measurement of the rate of coagulation in glass tubes amounts to doing it after addition to the blood of a "thromboplastic agent," which glass may be said to represent. Glass surfaces favor the action of clot-promoting factors in the blood, and hinder that of inhibitors like anti-thromboplastin. When blood is properly collected and placed in collodion or silicone coated tubes, it remains fluid from three to five times as long as in glass. It seems then that blood tends to maintain its fluidity, if placed under conditions resembling its natural environment. Estimates of its rate of coagulation under such conditions are a more sensitive index of the facts, than when the tests are done in glass. Standards for blood coagulation in glass supply a coarse yardstick, of use only when dealing with wide deviations from normal. The blood of patients with mild hemophilia, severe prothrombinopenia and thrombocytopenia usually have normal rates of coagulation in glass tubes; in silicone coated tubes significantly prolonged rates are the rule. Of the coatings now available, silicone seems to be the most effective.

The method used for the past two years in the study of our patients with hemorrhagic or thrombotic disorders consists in collecting the blood with siliconized syringes, and measuring the clotting time in three silicone coated tubes so arranged that, in the first tube, the blood is undiluted, and in the second and third tubes it is diluted 40 and 70 per cent respectively. By this means it is possible, first, to observe the behavior of the blood on a surface designed to preserve its fluidity, and secondly, to note the effect of disruption of the balance between coagulants and anticoagulants brought about by dilution.

Table I lists the clotting time of blood with various defects, as measured in glass, collodion and silicone coated tubes. If the blood is properly collected and its stability is high (e.g., hemophilic blood) a wide difference is observed between its rate of coagulation in glass when contrasted with that in silicone. When the stability of blood is reduced (posthemor-

rhagic blood) and its coagulability correspondingly enhanced, little or no difference may be observed between the rate of coagulation on the three types of surfaces. Other examples of different degrees of stability of the blood are given in the table. On glass, the rates of coagulation may not differ significantly from normal, though obvious defects in the blood are present. A difference becomes evident when the blood is allowed to clot on silicone or collodion surfaces. When the blood becomes hyper-

TABLE 1

THE RATE OF COAGULATION OF VARIOUS TYPES OF BLOOD IN CONTACT WITH THREE TYPES OF SURFACE (1 ML. OF BLOOD AT 38°C)

Surface of Tube	Clotting Time (seconds)					
	Normal (1)	Hemo- philic (2)	Hepar- inized (3)	Throm- bocyto- penic (4)	Pro- throm- bino- penic (5)	Post- hemorrh. Hyper- coagul- able (6)
Glass	358 (± 198)	2,820	985	350	530	175
Collodion	974 (± 351)	13,300	3,960	1,770	2,160	320
Silicone	1,756 (± 414)	> 6 hrs	18,900	2,590	3,710	410

1. Mean \pm standard deviation of readings from 8 normal subjects.

2. Patient with hereditary hemophilia

3. Patient receiving heparin for thrombophlebitis

4. Platelet count 20,000 per cu. mm. blood.

5. Prothrombin 13 per cent, 1-stage method.

6. Patient with menorrhagia for 1 month.

Prothrombin normal (1-stage method) in all patients except 5

lining endothelium remains intact or almost so, if stasis or other favorable factors are introduced.

The response of whole blood to dilution by physiological saline solution (0.85 per cent sodium chloride) supplies some additional information regarding the state of the equilibrium between coagulants and anticoagulants. Figure 612 gives examples of the results of dilution of normal blood and blood with various defects. When blood of high stability having an excess of clot inhibitors (such as that of hemophiles or heparinized patients) is diluted, it clots faster, until dilution is carried to a point where the concentration of prothrombin is so reduced that the rate of coagulation begins to lengthen. Normally, dilutions below 20 per cent are necessary to produce this effect. The blood of patients with hemophilia or that of heparinized patients can be diluted to lower con-

is small or slowly liberated, or enough anticephalin is available for its inactivation. In any event, if there is insufficient cephalin or thromboplastin, prothrombin remains unconverted, and without thrombin there is no clotting.

Second Phase.—If enough cephalin is available, the process goes on to the second phase, or the conversion of prothrombin to thrombin. The rapidity of this conversion depends on the amount of cephalin liberated from the cells and not inactivated by anticephalin (or, in other words, on the results of the first phase), and an "Accelerator Factor" also designated as Ac-globulin, Factor V, "labile factor" or thrombogen. Since shed normal blood contains an excess of platelets, prothrombin and ac-globulin, once changes in these coagulants get under way their products mount up rapidly, the reaction assuming an autocatalytic character.

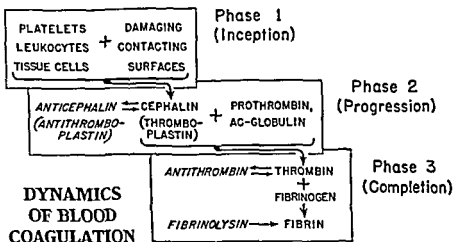


Fig 611

This is especially so when the surface, rate of movement of the blood and other surrounding conditions favor changes in the coagulants and hinder the action of the inhibitors, which in the usual concentrations are powerless to check a rapidly mounting titer of thrombin.

Third Phase.—As thrombin is formed the process enters its third phase, namely the action of thrombin on fibrinogen with formation of fibrin. Here the amount of fibrin formed depends on the rate and amount of thrombin available and this in turn hinges on the existing quantity of *prothrombin* and *Ac-globulin* and the effectiveness of antithrombin. In normal blood, the titer of thrombin is built up so rapidly that it acts on fibrinogen before antithrombin has much opportunity of exerting its full action.

The density of the clot depends to a large extent on the quantity of fibrinogen present, and the promptness and thoroughness of its reactivity to the formed thrombin. In normal, stagnating, "ex vivo" blood, nearly all the fibrinogen is changed into fibrin, once coagulation starts. When the inception and progression phases of coagulation are

rhagic blood) and its coagulability correspondingly enhanced, little or no difference may be observed between the rate of coagulation on the three types of surfaces. Other examples of different degrees of stability

clot on silicone or collodion surfaces. When the blood becomes hypercoagulable because of a depletion of inhibitors (as after a severe hemorrhage) it clots in silicone coated tubes almost as rapidly as if it were in a glass tube. Such blood may well clot within the vessels, even though the

TABLE 1

THE RATE OF COAGULATION OF VARIOUS TYPES OF BLOOD IN CONTACT WITH THREE TYPES OF SURFACE (1 ML. OF BLOOD AT 38°C)

Surface of Tube	Clotting Time (seconds)					
	Normal (1)	Hemo- philic (2)	Hepar- inized (3)	Throm- bocyto- penic (4)	Pro- throm- bino- penic (5)	Post- hemorrh. Hyper- coagul- able (6)
Glass	388 (± 198)	2,820	985	380	530	175
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centrations before its rate of coagulation exceeds that of the undiluted control. The bloods of patients with prothrombinopenia and thrombocytopenia behave on dilution like normal blood,¹ provided their content of clotting inhibitors has not been proportionally reduced. In such instances the blood will be hypercoagulable in silicone tubes, and dilution will prolong the rate of coagulation, even though prothrombin and

**EFFECT OF DILUTION (0.85 % NaCl)
ON RATE OF COAGULATION
OF BLOOD WITH VARIOUS DEFECTS**
(Total vol.—1 ml. Silicone tubes, 38°C.)

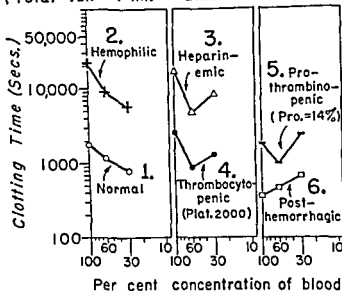


Fig. 612.—Blood collected with silicone coated syringes and needles and placed in three silicone coated tubes.

Tube 1: 1 ml. of blood (100 per cent blood concentration).

Tube 2: 0.6 ml. of blood plus 0.4 ml. 0.85 per cent Sodium chloride (60 per cent blood concentration).

Tube 3: 0.3 ml. blood plus 0.7 ml. 0.85 per cent sodium chloride (30 per cent blood concentration).

The heparinemic patient was receiving heparin intravenously because of thromboembolic disease. The posthemorrhagic blood was obtained from a patient after a massive hematemesis (peptic ulcer).

platelets be greatly decreased. The hypercoagulable blood from patients who have had a recent acute hemorrhage likewise stands dilution poorly; its rate of coagulation is prolonged from the start (Curve 6, Fig. 612).

Simple dilution of blood in silicone tubes may then be used to detect variations in its stability. Patients whose blood conforms to the normal curve (Curve 1, Fig. 612) are well provided with stabilizing inhibitors, and should need no anticoagulant therapy. Those whose blood behaves as in Curve 6 may have to have anticoagulant therapy, if other clinical indications make the likelihood of thrombosis high.

thromboembolic complication in patients with such tendencies, the following precautions may be profitable:

(a) Reduce the duration and extent of the operative procedure to the minimum compatible with necessity.

(b) Use gentle manipulation of the viscera, especially where there are large collections of veins in dependent areas of the circulation (pelvis, groin).

(c) Attempt to control or reduce an infectious process by prompt and adequate antibiotic therapy.

(d) Avoid excessive blood loss and the consequent blood dilution and hypercoagulability.

(e) Consider the use of anticoagulants whenever there exists, or has existed, occlusive vascular disease or previous thromboembolism.

(f) Discontinue vitamin K therapy promptly after an operative procedure, when it has become clear that there is no further danger of bleeding.

3. Coagulants and Anticoagulants.—If the examinations have disclosed that a defect in coagulation is responsible for the disorder, then efforts should be made to detect which of the aforementioned factors is involved. The two commonest causes of delay in the rate of blood coagulation are a diminution in prothrombin and in the blood platelets. Either or both defects when present will upset the equilibrium between coagulants and anticoagulants, the anticoagulants then assuming the dominant role. A less commonly detected cause is an increase in antithromboplastin, examples of which are being reported with increasing frequency.³ In so far as the prothrombinopenia is concerned, the most rapid way of correcting it is with a transfusion of blood or plasma. Most times it is not necessary that the plasma be fresh, since even when it is as old as ten days its content of prothrombin is sufficient for the temporary correction of the deficiency. Vitamin K in the form of one of the water-soluble compounds should also be given to aid in the production of prothrombin. The amount required varies with the capacity of the liver for prothrombin formation. In most instances 2 to 5 mg. by mouth or parenterally daily should suffice. If there is advanced hepatic insufficiency, or after prolonged Dicumarol therapy, doses between 100 and 500 mg. daily may be required.

A deficiency of platelets can best be combated temporarily by a transfusion of fresh unmodified blood (direct blood transfusion). If a direct blood transfusion cannot be given, the next best resort is a transfusion of freshly citrated blood, collected in such a manner that there is a minimum of injury to the blood platelets. The ordinary vacuum suction methods generally available for the collection of citrated blood are *not* suitable. The blood should be collected in 50 or 100 cc. lots from the

donor, into a syringe holding the required amount of sterile citrate solution; immediately after the entire collection is finished, the citrated blood is infused or injected into the recipient, thereby reducing the chance for any lasting damage to the platelets to occur.

Sometimes there is reason to believe that a hypercoagulable blood is playing a part in producing or enhancing thromboembolism. Perhaps the commonest causes for hypercoagulability are (a) an increase in the number of platelets and (b) a decrease in antithromboplastin and perhaps antithrombin with a resulting more rapid conversion of prothrombin. No satisfactory method for reducing the number of platelets in a patient with thrombocytosis is yet available. To overcome hypercoagulability of the blood, two measures are available:

(a) Increase the anticoagulant content of blood by administering an inhibitor like heparin which has an antithromboplastin as well as antithrombin action.

(b) Reduce the effectiveness of the coagulants by the use of Dicumarol, which interferes with the formation of prothrombin and thereby makes less thrombin available for clotting.

In spite of a large working margin of safety it is important to remember that any measure designed to influence this mechanism requires frequent control, since the forces within the body, being constantly at work, may tend either to exaggerate the effect of the therapy or offset it, in one way or another. Anticoagulant therapy is intended not only to maintain the fluidity of the patient's blood but possibly to increase it somewhat over a temporary period during which there is reason to believe (because of a recent operative procedure, previous thrombotic episodes, subendocardial or subintimal infarctions) the fluidity of the blood is impaired, or may with profit be enhanced. With the means available *at present*, most anticoagulant therapy is best regarded as a therapy of emergency, as is for example the treatment of congestive heart failure or of diabetic acidosis, except that, unlike these states, the "emergency" may extend into several weeks, or as long as existing conditions strongly favor the development of thromboembolic complications. It follows that the patient receiving anticoagulants must be under close observation to make reasonably certain (a) that the desired fluidity of the blood is *actually* obtained and (b) that there is no excessive bleeding.

To date heparin and Dicumarol remain the most commonly used anticoagulant agents. Future efforts to maintain and enhance the fluidity of the blood will perhaps involve the use of the natural inhibitors found in the blood and largely responsible for maintaining it fluid. There are indications that a lipid antithromboplastin is concerned in this function.⁵ The fact that the duration of its effect when injected intravenously is greater than that of heparin similarly injected⁶ may make the use of the lipid preferable to heparin in the management of thromboembolic disease.

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FLUID AND ELECTROLYTE REPLACEMENT FOR THE SURGICAL PATIENT

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The general concepts governing fluid exchange in the surgical patient have been discussed in a recent review article by Ravdin and Walker.¹ There is general agreement as to the care of the simple surgical case. However, the care of the patient with exceptionally large losses of fluid from the stomach and small bowel remains, at times, a difficult problem, and this present report is devoted largely to it. A method of handling such a case is outlined and some general principles in the management of such cases are discussed.

REPORT OF A CASE

L. Mc. A. was a 68 year old white man admitted following a four day history of generalized abdominal pain, distention, nausea and vomiting. Upon admission he was found to markedly dehydrated, with evidence of small bowel obstruction. His blood volume was two liters below normal, with an hematocrit reading of 70 per cent cells. Determination of "thiocyanate available fluid" showed a deficit of about 4 liters. His plasma chloride level was 94 milliequivalents per liter. Prior to operation he was given a liter of blood, 650 ml. of plasma, 1100 ml. of physiological saline solution and 1100 ml. of 5 per cent glucose in water by intravenous route.

At operation he was found to have an appendiceal abscess obstructing the blood supply to about 3 feet of terminal ileum with resulting gangrene of this portion of the small bowel. The nonviable ileum was resected, a double barrelled ileostomy being formed. The appendiceal abscess was drained and the appendix removed. On the third postoperative day, the ileostomy began to drain 3 to 4 liters and an additional 1500 ml. were removed from the stomach through a Levine tube. Figure 614 illustrates the amounts of electrolyte being lost by this patient.

During this period of marked fluid and electrolyte loss, it was necessary to collect all drainages and to analyze aliquots for their electrolyte content. As nearly as possible, a quantitative replacement was made of the fluid lost. It was helpful to estimate the total chloride requirement initially from the "thiocyanate available fluid" and the plasma chloride level, and to keep a record of the chloride exchange for estimation of daily fluid requirements. A

four hour period.

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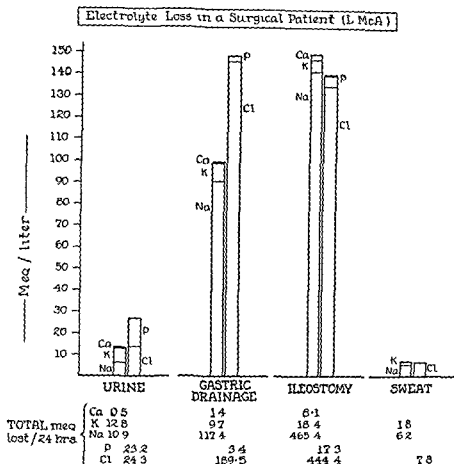


Fig 614.—The maximum twenty-four hour electrolyte loss in a surgical patient draining small bowel content from an enterostomy. This figure shows graphically the relative concentration of the common electrolytes in urine, gastric drainage, ileostomy drainage and in sweat in the case of the patient reported. The stick graph gives concentrations in milliequivalents per liter of the respective fluids

The subscript lists the total amounts of electrolyte lost by this patient in a given twenty-four hour period. This represents the maximum loss during the period of drainage which lasted for several weeks. Quantitative collection was made of urine and drainage. The sweat electrolyte content was estimated by analysis of filter paper patches placed on the patient's skin.

It was possible to maintain this patient with large volumes of intravenous electrolyte solution, including Ringer's solution and potassium chloride. Repeated blood transfusions were also necessary. Eventually it was possible to close the ileostomy and this patient has made a complete recovery.

This case is illustrative of the small percentage of general surgical patients whose fluid balance problems are not easily handled. The patient with a fistula at some point in the stomach or small intestinal

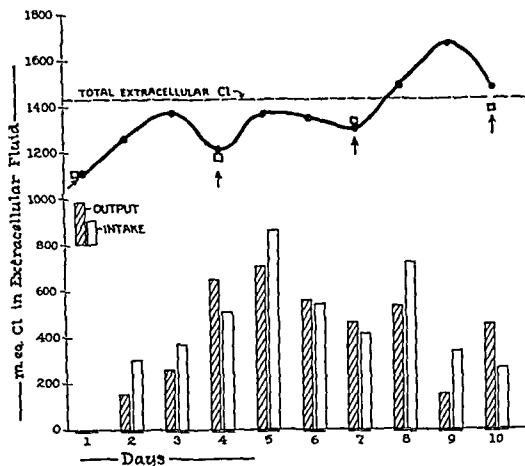


Fig. 615.—Total exchange in extracellular chloride. This figure illustrates the exchanges occurring in the total extracellular chloride in the case reported. By "total extracellular chloride," the author means that amount of chloride found in the plasma volume and in the interstitial fluid. This is calculated clinically by measuring the "thiocyanate available fluid" and the plasma chloride concentration. The total extracellular chloride is calculated on the assumption that the concentration of chloride in thiocyanate fluid is 1.0%.

patient's actual extracellular chloride was calculated and on the basis of this and a measurement of the total chloride loss and intake on succeeding days, the fluctuations in total extracellular chloride were calculated and plotted as the curving line. As a check on the reliability of such calculations, additional determinations of the "thiocyanate available fluid" and of plasma chloride were made at several points, and the calculated total extracellular chloride on the basis of the data is plotted on the graph as a small square. It will be seen from inspection that there is a reasonably close agreement between the value calculated from loss and gain of chloride each day, and the value calculated from the actual measurement of total extracellular chloride.

tract loses large amounts of water and electrolyte which would be normally reabsorbed. There is often serious impairment of nutrition. The escape of intestinal secretions may take place through an abnormal passage, created by trauma, infection or operation. The loss of secretions

may occur quite as readily when prolonged suction is applied to an indwelling tube in the stomach or small bowel. These patients may lose as much as 7 liters of electrolyte solution each day. The maintenance of normal water and salt relationships is often a difficult matter in such cases.

I have found it helpful to estimate the deficits in these cases of (1) total circulating plasma protein and red cell mass, (2) water, particularly the interstitial water, and (3) the sodium and chloride ions.

ESTIMATION OF DEFICITS IN DEHYDRATED PATIENTS

Estimation of Circulating Blood Volume.—The determination of total circulating plasma protein and red cell mass necessitates measuring the plasma volume or total blood volume.

The technic for measurement of any volume of fluid within the body is based on the principle of dilution. A known mass of a traceable substance is introduced, which by its chemical or physical properties is presumed to be confined to the fluid space in question. After adequate mixing of the test substance within the fluid compartment, a sample of the fluid is analyzed for the test substance and the effective volume of the fluid in question can be determined from the concentrations measured.

Plasma volume may be conveniently measured by the use of the blue dye T-1824.^{2, 3} This substance mixes with the circulating plasma volume in the normal patient within about fifteen minutes. It is slowly lost from the circulation at a rate which is a constant for the given patient under the conditions of the given day. It has been found necessary to know accurately the amount of dye given and to obtain plasma dye concentrations at three different times following injection (usually fifteen, thirty and forty-five minutes). In addition, any samples showing hemolysis should be discarded.

Knowing the plasma volume and the plasma protein concentration, one may calculate the effective circulating plasma protein. In a similar manner, using the hematocrit reading, one may obtain a value for red cell mass or total blood volume.

These figures thus obtained are compared with a theoretical normal figure related to height and ideal weight. From such comparisons the deficit is measured and replacement therapy can then be instituted.

Estimation of the Interstitial Water.—This fluid volume is also measured with a dilution technic, using a test substance which has the ability to diffuse uniformly throughout the extracellular space, including the plasma volume. Substances employed fall into two general groups; the inert carbohydrates and electrolytes. In the former group are such substances as inulin and mannitol, while the electrolytes used commonly are sodium, chloride and thiocyanate. The determination of the carbohydrates is time-consuming, whereas, the electrolytes are more easily determined. None of the electrolytes are ideal for they all pass into cells

to some extent. However, here again, as with the T-1824 technic, if the normal values are determined in the same manner, one obtains reliable data on relative shifts in this fluid compartment.

For purposes of the present study, 0.7 gm. of thiocyanate⁴ (20 ml. of a 5 per cent solution of sodium thiocyanate) were injected following withdrawal of a blank blood specimen. Allowing one hour for equilibration, a second blood specimen was taken, as well as a quantitative collection of urine voided during the hour. The "thiocyanate available fluid" space was then calculated from the concentrations, allowing for urinary loss. Care was taken to avoid determination of the thiocyanate space while patients were receiving intravenous glucose solution. Other investigators have shown in experimental animals that an infusion of 5 per cent glucose in water increases permeability of muscle and skin cells for thiocyanate, thereby producing a spuriously high result. This observation has been confirmed in the human subject in the present series of observations. Apparently the effect is noticeable only at the time that the glucose infusion is in progress.

By subtracting the plasma volume from the "thiocyanate available fluid" volume, one may obtain the interstitial fluid volume.

Estimation of Sodium and Chloride Deficits (Knowing the "thiocyanate available fluid" volume and the plasma volume).—In the case of the markedly dehydrated patient seen for the first time in the hospital, one is faced immediately with the problem of correcting such a state and possibly of preparing this patient for emergency operation.

It has been found helpful to make an immediate estimate of the patient's plasma and blood volume, serum sodium and chloride, and of the "thiocyanate available fluid". These determinations require about one and one-half hours time during which replacement of blood and of salt solutions may be in progress, the total amount replaced being subject to the results of the analysis.

An index to the amount of salt-containing fluid needed in such emergency cases may be obtained from the "thiocyanate available space" and the plasma chloride concentration. Assuming for the purposes of rough calculation that the chloride concentration in the extracellular space is the same as that of the plasma, then the following formula will give the required chloride replacement in milliequivalents.

Where W = body weight in kilograms
 P = plasma chloride concentration in milliequivalents
 E = measured thiocyanate space in liters

Then:

$21W - PE$ = chloride deficit in milliequivalents.

Replacement of this chloride deficit is then accomplished with physiological saline solution on the basis that 1 liter of 0.9 per cent sodium chloride contains approximately 154 milliequivalents.

The advent of the flame photometer has greatly simplified determination of sodium and potassium content of biological fluids. Knowing

sodium concentrations of plasma, it is possible to calculate sodium deficits in these patients in a manner similar to that used for total extracellular chloride.

MAGNITUDE OF WATER AND ELECTROLYTE LOSS

The pattern of electrolyte depletion is dependent naturally on the volume and salt content of the secretion lost. Table 1 illustrates the relative concentrations of some electrolytes in secretions lost from the upper gastro-intestinal tract.

TABLE 1

TOTAL EXTRACELLULAR CHLORIDE AND CHLORIDE EXCHANGE (mEq)

L. Mc. A. 68 kg Theoretical normal extracellular space 14,300 ml.

Day	Out	In	Plasma Chloride	Thiocyanate Space	Measured Extracellular Chloride	Estimated Extracellular Chloride
	mEq	mEq	mEq/l.	ml	mEq.	mEq
1	151	309	92	12,300	1110	1268
2	263	373	88			1378
3	658	509	87	13,700	1190	1219
4	711	861	87			1369
5	565	546	85			1350
6	466	415	92	14,400	1320	1299
7	535	727	106			1491
8	155	339				1675
9	456	261	109	15,300	1420	1480
10	353	320	95			
11	268	420	102			

In general, gastric juice contains a preponderance of chloride although sodium and phosphate are lost in considerable quantity. The patient with pyloric obstruction, therefore, will develop an alkalosis, due to the loss of excessive quantities of chloride ion. There will be a marked dehydration accompanied by some lowering of total base as the result of sodium loss and as a compensatory action by the body to avoid extreme alkalosis.

The loss of bile and pancreatic juice in addition to gastric juice increases the volume of fluid and electrolyte lost. Because of the composition of these secretions, the loss of sodium is proportionately greater than in the loss of gastric juice alone.

The volume of secretion lost is as important as the electrolyte concentrations. Patients with pyloric obstruction will lose 2 to 3.5 gm. of sodium and 6 to 10 gm. of chloride in a total volume of 1.5 to 2.5 liters. The patient with a duodenal or high jejunal fistula will lose 6 to 10 gm. of sodium and 10 to 20 gm. of chloride in a volume of 3 to 5 liters of fluid.

The patient with a low small intestinal fistula will lose a secretion approximating mammalian Ringer's solution. The volume of fluid lost will be much greater than at a point high in the gastrointestinal tract, amounting to as high as 6 to 8 liters a day, containing as much as 35 gm. of sodium chloride.

The problem of replacement therapy in these patients is almost an individual matter. In general, it is obvious that they must have water

TABLE 2
CONCENTRATION OF ELECTROLYTES LOST IN GASTRIC SECRETION

Patient	Milliequivalents per Liter				
		Na	K	Cl	P
P. B.	Pyloric obstruction	88	6	34	10
J. K.	Pyloric obstruction	66	15	88	89
M. E.	Pyloric obstruction	57	6	112	28
H. deG.	Gastric suction	116	6	126	51
C. B.	Gastric resection	110	16	68	1
A. P.	Gastric resection	70	11	25	15
H. M.	Gastric resection	54	5	10	3

TABLE 3
THE CONCENTRATION OF CERTAIN IONS IN A NUMBER OF SOLUTIONS COMMONLY USED FOR INTRAVENOUS ADMINISTRATION

	Na		K		Cl	
	Grams per 100 ml	mEq./l.	Grams per 100 ml	mEq /l	Grams per 100 ml	mEq /l
PSS	3.33	145			5.17	145
Amigen	0.79	34	0.07	1.8	1.21	34
Ringer's	3.11	135	0.24	8	4.30	121
Na and KCl	1.67	73	3.14	80	5.43	153
Plasma	3.34	145	0.15	3.8	3.65	103
Blood	1.84	80	0.20	5.1	2.91	82
2% NH ₄ Cl					13.3	372
M/6 Na Lactate	3.83	162				

and the proper salt replacement to overcome dehydration. The use of glucose is preferred to other sources of caloric intake because it supplies added water in the course of metabolism. The use of protein in the dehydrated patient has the disadvantage that its metabolism requires water for excretion of nitrogenous wastes.

No two patients with pyloric obstruction will lose fluid of the same electrolyte pattern. This is equally true for fluid loss from any part of the bowel. Table 2 illustrates the electrolyte content of gastric drainage

in a group of patients with pyloric obstruction, and in a few patients who have had delayed gastric emptying following gastric resection. The difference in gastric acidity alone is responsible for much variation.

The same variation in electrolyte content is found among patients losing fluids from other parts of the bowel. In addition, patients may lose secretions from more than one portion and their total loss will be correspondingly greater.

Because of these variations, it has been found advisable to have available a variety of solutions for correction of fluid deficits. A list of some solutions with their salt contents is given in Table 3. Using these singly or in combination, corrections may be made for deficits in circulating blood volume, dehydration and coexisting alkalosis or acidosis.

THE OCCURRENCE OF POTASSIUM DEFICITS IN DEHYDRATION

The patient on parenteral fluid replacement, taking nothing by mouth for long periods of time, will frequently develop low serum potassium levels. Values of the order of 2 milliequivalents per liter are commonly seen, the normal range being 3.5 to 5 milliequivalents. In spite of a complete absence of potassium in the intake, these patients will continue to lose potassium in the urine. There is apparently little or no attempt on the part of the kidney to conserve this cation. There is also a continued loss in gastrointestinal secretions which, with the urinary loss, may total several grams daily.

The objective evidence for a state of potassium depletion exists in observation of electrocardiographic changes in these patients and in measurement of the amount of retention of administered potassium.^{4, 6}

Patients in diabetic acidosis or patients with low serum potassium levels during a period of prolonged parenteral feeding without potassium replacement will develop characteristic Ekg changes, such as prolongation of the S-T segment and flattening or inversion of the T waves. These changes are reversed upon administration of potassium solutions.^{7, 8, 9} These same patients when given potassium solution will retain the greater portion of it, whereas, normal individuals excrete much of the added electrolyte.

Apparently this state of potassium depletion is mediated in large part by the kidney in the absence of potassium intake. Regardless of the lack of potassium in the intake in these patients, the kidney continues to excrete 0.5 to 1 gram of potassium daily. In a state of dehydration, water is lost from the plasma volume and extracellular fluid volume initially. As dehydration advances, there is a loss of water from the intracellular space with a resultant shift of sodium into the cells and potassium out of the cells. The potassium thus displaced is immediately excreted. The effect of this so-called depletion is as yet not clearly understood. States of otherwise unexplained alkalosis have been noted with hypochloremia which were refractory to therapy until potassium is also given. With plasma sodium concentrations in the normal or low

normal range, such patients develop blood pH of the order of 7.55 and show clinical tetany in extreme cases.

REPLACEMENT OF OTHER IONS

The question may be logically raised as to the importance of replacing all substances lost in abnormal fluid drainage. Obviously this is ideal, but with the methods available at the present time it has seemed impractical from the point of view of the number of patients requiring such care and the time and effort required to do the requisite analyses to make up the fluids for replacement.

In cases of prolonged fluid loss from such routes as duodenal fistula or ileostomies, it has been customary to use a mammalian Ringer's solution and to supply additional fluid and ions as required to correct obvious imbalance.

COMMENT

In the management of the simple surgical case, one may assume certain average fluid losses and base replacement therapy upon these figures with reasonable assurance.

In a small percentage of surgical cases, there is an exceptionally large loss of fluid and electrolyte by abnormal routes. These patients present complex problems in the estimation of existing deficits and in estimation of daily replacement needs.

It is believed that one may obtain information useful in the handling of this type of patient from a few estimations.

An estimate of the plasma volume is helpful when considered in conjunction with determination of plasma protein and the hematocrit reading. One may calculate deficits not only in the fluid volume of the plasma but also in the total circulating protein and in the red cell mass or total circulating blood volume.

An estimate of the "thiocyanate available fluid" gives a clue to the state of hydration of the interstitial space. The "thiocyanate available fluid" minus the plasma volume is the interstitial space. In the normal individual, the "thiocyanate available fluid" is about 21 per cent of the body weight.

Determination of plasma chloride and sodium in conjunction with the "thiocyanate available fluid" permits the calculation of total extracellular chloride and sodium. This is useful as a base line estimate of electrolyte deficiency and makes possible more reliable estimates of the needs of the body for sodium and chloride than have been possible by clinical methods based on ionic concentrations alone.

By starting with an estimation of the total extracellular chloride and, keeping a careful record of volume and electrolyte content of all secretions lost, the clinician can estimate the patient's daily fluid and electrolyte replacement needs.

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